



RFIC46

Conducted RF immunity test system controller

User Manual

CAUTIONS

1. ALWAYS ENSURE THAT THE SYSTEM IS FULLY CONNECTED PRIOR TO START OF ANY TEST OR CALIBRATION SEQUENCE.

This system can generate significant levels of RF power. The amplitude of this power is controlled via feedback from the relevant transducer. If this feedback is not correctly connected, the applied RF power may rise to maximum which may damage your test equipment and/or EUT.

RF power amplifiers must always be connected to a suitable matched 50 ohm load or transducer before any power is applied. Failure to ensure this may result in damage to the power amplifier.

2. CHECK THE MAINS VOLTAGE RATING OF THE RFIC46 SYNTHESISER BEFORE CONNECTING THE MAINS POWER.

This item is not dual voltage.

3. ALWAYS CHECK THE GROUNDING ON CDNS AND OTHER INJECTION DEVICES, AND ANY CALIBRATION ADAPTORS.

Failure of any grounding may cause loss of control and potential damage to injection devices and/or EUT.

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1. INTRODUCTION

EMC compliance testing requirements include a check of the susceptibility of a product to RF interference coupled into it via any cables that may normally be connected. The standard that defines this test is IEC61000-4-6. This test normally covers the frequency range 150KHz to 80MHz or sometimes to 230MHz. The level of applied RF (the stress level) may be defined by the particular product specific standard, but otherwise the default values are 3V (rms) for products intended for domestic & commercial environments, and 10V for Industrial environments. Although the test seems (at first sight) to be very straightforward, in practice it requires great care in terms of setup and application.

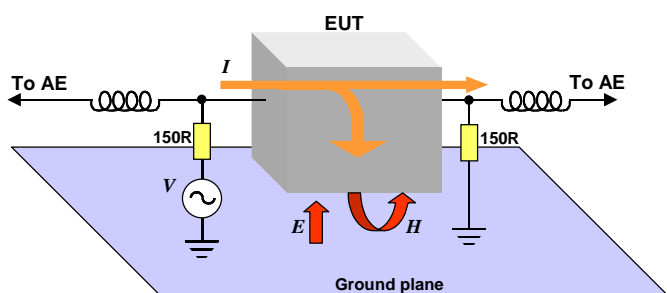
Key issues are:

- Repeatability
- Coupling
- Stress level calibration.

The first two issues are dependant on the test setup, especially given the high frequencies involved. At the higher frequencies, capacitive coupling to surrounding objects and impedance matching become critical. For these reasons, test configuration and setup are critical.

Figure 1 shows the general principles. The product is effectively held in a 150ohm environment, supported 10cm above a grounded reference plane, with all external connections impedance matched so that the 150ohm overall impedance to ground is maintained. Significant points to note are ...

- All cables are impedance matched for the duration of the test.
- This includes any earth or grounding connections.
- The product is physically held above a ground plane on insulating blocks or supports.
- The stress signal is applied to one cable at a time, and each cable is tested in turn.



Full details to cover the differing types of products are given in the standard IEC61000-4-6.

Figure 1. Outline of conducted immunity test.

During the test, the 'stress' frequency is stepped in increments between a start frequency and an end frequency. The increment is specified as a percentage of the current frequency, typically 0.5% or 1%. At each frequency, the stress signal is injected at the relevant level (V) and a 1KHz, 80% depth AM modulation applied. The product is monitored for any degradation in performance or operation. This 'dwell time' should be long enough to ensure any change to the product can be detected. Once this dwell time is completed, the frequency moves on to the next step and the test is repeated.

Compliance Criteria

The pass/fail criteria depend on the purpose and function of the product. It may also be defined by the customer's expectations.

Criteria A: no significant degradation in operation or function allowed. This criteria applies to any product that has safety implications.

Criteria B: Some degradation in operation may occur, but the product recovers once the stress is removed without any operator intervention. No change in operating state or loss of data occurs.

Criteria C: Operation of the product is affected, and operator intervention is needed to recover normal operation. Again, no loss of data is allowed.

2. Stress injection

There are three techniques that can be used for the injection of the RF signal on to the cable: CDN, BCI and EM clamp. The CDN is the preferred device according to the standard.

CDN (Coupling/Decoupling Network)

The function of the CDN is quite simple.. To couple the RF signal into the cable connected to the EUT, and to Decouple (block) the RF signal from the external equipment (Associated Equipment or AE). This technique is the most efficient (lowest RF power level for a given required stress level) But, it is intrusive, it requires a break in the cable.

Fig 2 shows the basic principle of the CDN. Unfortunately, if the cable is unshielded, the stress must be applied to each of the cable cores equally, whilst maintaining the impedance requirements. Fig 3 shows the

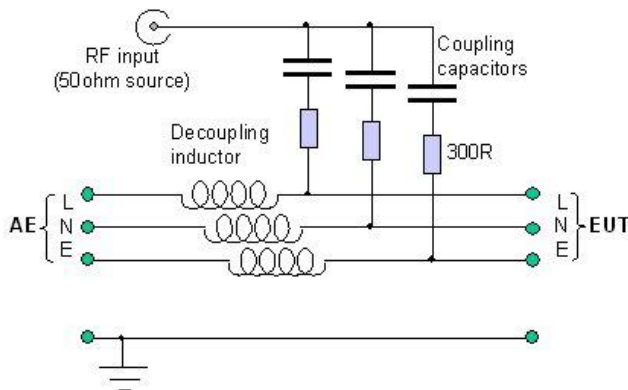


Figure 3. M3 CDN simplified schematic

cables. This is achieved using a technique that incorporates 'programming' features in the cable connectors.

Fig 4 shows the RF signal path. Note how the inductor prevents the RF coupling to the AE, and the internal link in the CDN for the ground connection. This makes it imperative that the CDN enclosure is properly bonded to the ground plane otherwise incorrect stress levels are likely to be applied to the EUT.

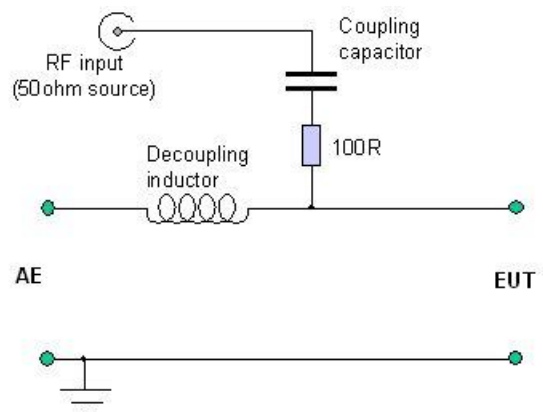


Figure 2. Basic CDN concept

arrangement for a 3 core mains cable. This is a type M3 CDN. The net result is that each type of cable requires its own specific CDN. So for instance, an M3 type cannot be used with a 2 core mains cable (this requires an M2 CDN). However the Laplace range of 'Versatile' CDNs is able to cope with multiple cable types, so, for example, the M3 type will work correctly with M2 and M1

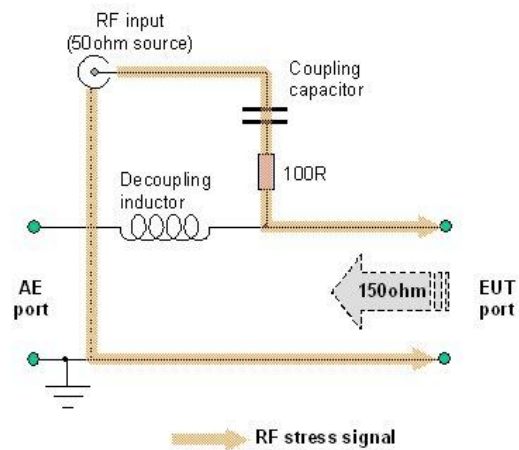


Figure 4. RF signal path

EM Clamp

This technique has the advantage of not requiring a break in the cable, although more RF power is required to create a given stress level. The stress is applied by capacitive and inductive coupling into the cable and a series of split ferrite rings provide the 150ohm impedance matching over much of the required frequency range. The length and size of the clamp can be a problem in some circumstances. The overall impedance is not so well defined as with the CDN.

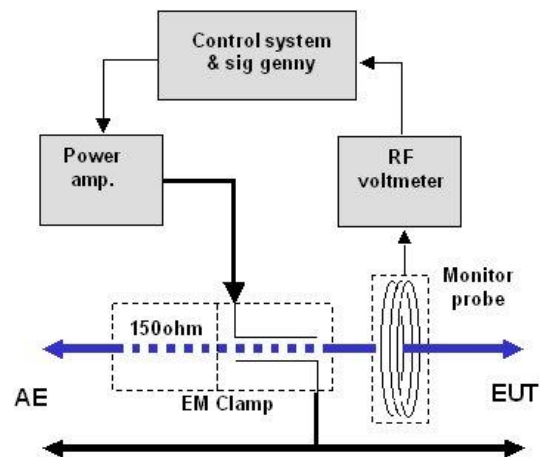


Figure 5. EM Clamp technique

BCI (Bulk Current Injection clamp)

This is generally only used when other techniques are impractical. It is non-invasive (does not require a break in the cable) but:

- Requires a significantly higher level of RF power for a given stress level.
- Does not provide any impedance matching.
- The AE is stressed equally as the EUT
- Cables resonances are virtually unavoidable at the higher frequencies.
- An additional current probe is required to monitor the applied stress level.

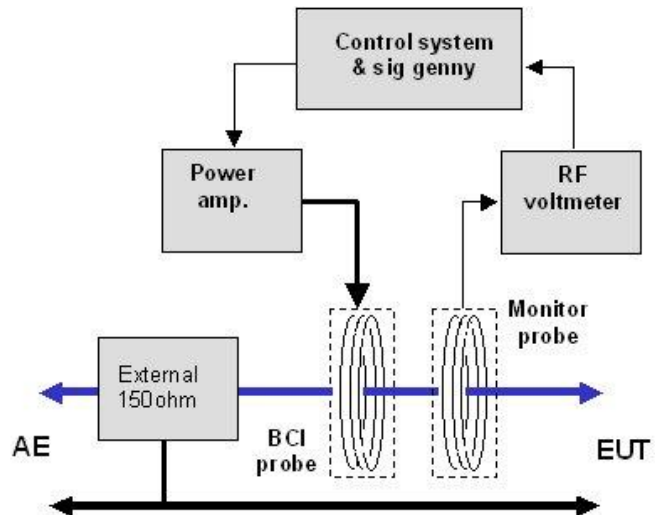


Figure 6. BCI probe technique

BCI and EM Clamp techniques are often specified for military or automotive tests. One key advantage is that they can be used on complete cable bundles.

2.1 Cable matching

When more than one cable is attached to an EUT, the 'untested' cables need to be impedance matched to 150ohm. This can be accomplished by using a CDN or by adding ferrites to the cable. The CDN has the advantage that it is a known impedance and covers the required frequency range. Ferrites will be an essentially unknown quantity but will offer a lower cost solution. Where multiple cables are involved, each must be tested, so a full set of CDNs are required anyway. Note that only 1 'matching' CDN should have a 50ohm terminator fitted.

See annex A for a discussion regarding 'Best Practice'.

2.2. Setting the stress level.

The standard IEC61000-4-6 specifies that the stress level is defined as the open circuit source voltage (V_s). This voltage will have a source impedance of 50ohm.

It is then connected to the test system, which nominally has an impedance of 150ohm. (except that the BCI probe will have an input impedance of 50ohm).

The calibration fixtures replicate these requirements. It is clear that the actual voltage applied to the EUT cable is a fraction of this source voltage. For 150ohm systems (CDN and EM Clamp), the voltage at the output of the 150/50ohm calibration fixture is 1/6th of V_s (15.6dB lower) and for the 50ohm BCI system, the voltage is 1/2 of V_s (6dB lower).

So when calibrating a test in the 'conventional' technique, the stress level at the output of the calibration fixture is set either 15.6dB or 6dB lower than the nominal stress level.

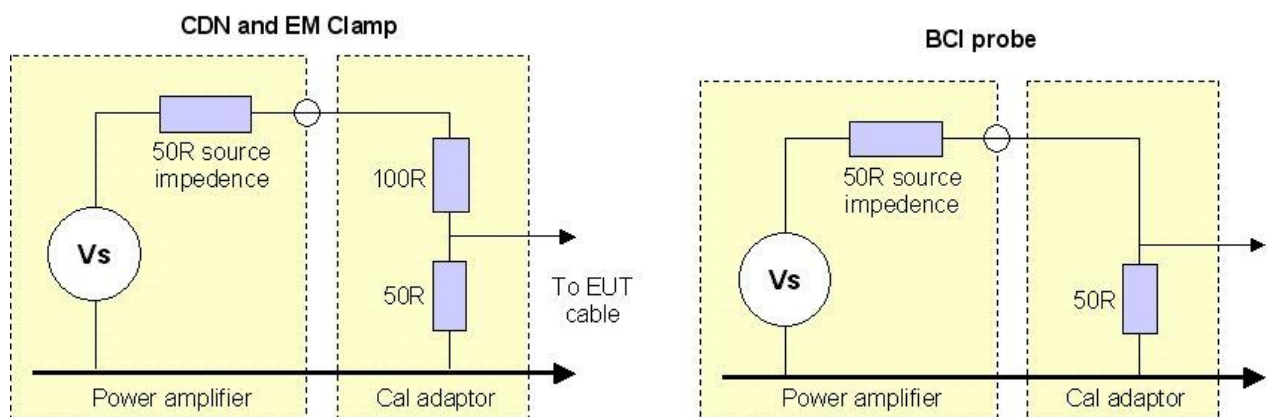


Figure 7. Setting the level

3. Testing Strategies

Basic choices

There are two sets of alternative techniques, one set related to the test strategy and one set related to the injection technique.

Test Strategy

The Standard IEC61000-4-6 specifies the use of a substitution technique for setting the stress level. The RFIC system offers that technique, (strategy) plus an alternative technique based on the use of 'Enhanced' CDNs. This alternative strategy is not described in the standard, but does offer several advantages.

Key differences are:

- The conventional strategy is strictly compliant. But the alternative technique will generally provide a more consistent stress level. This may not be a good feature. The actual stress level imposed on the EUT in the real world will be very dependant on the EUT input impedance. If this is high, the voltage stress level will be high. The conventional technique allows this variation due to the EUT characteristics. So the imposition of a more consistent stress may be retrograde. The Enhanced CDN overcomes this issue by monitoring the stress level at the RF input to the CDN, not at the EUT cable. This problem does however apply to the use of an enhanced mode when EM Clamps or BCI probes are used. In these

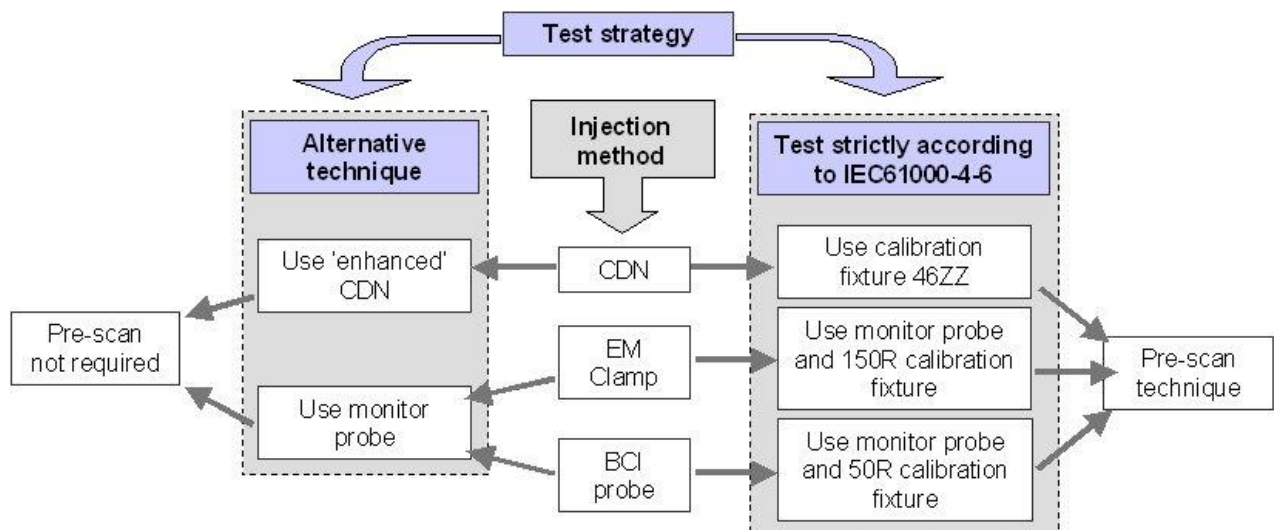


Figure 8. Overview of test techniques

instances, the feedback is obtained from current monitor clamps fitted to the EUT cable, and are thus measuring the stress level at the EUT cable. This negates the effect of the EUT input impedance.

- Alternative technique is quicker (no need for a calibration 'pre-scan').
- Alternative technique does not require the 6dB attenuator in the RF output feed to the CDN. This halves the required power rating of the power amplifier.
- The alternative technique cannot be used with 'conventional' CDNs, but can be used with 'Enhanced' CDNs, and, subject to some further considerations, EM Clamps and BCI probes too.

The conventional strategy requires 2 'scans' through the frequency range. An initial 'scan' with the EUT substituted by a calibration fixture. This fixture involves a 150R to 50R adaptor. The output from this adaptor is monitored with an RF Millivoltmeter and the applied RF level adjusted so that the monitored level maintains the correct stress level. See Fig 9. The power settings required to achieve this correct stress level are recorded. The EUT is then connected and the second scan performed using the recorded power settings. The RFIC46 hardware includes the millivoltmeter and the control system necessary to level the RF output as required.

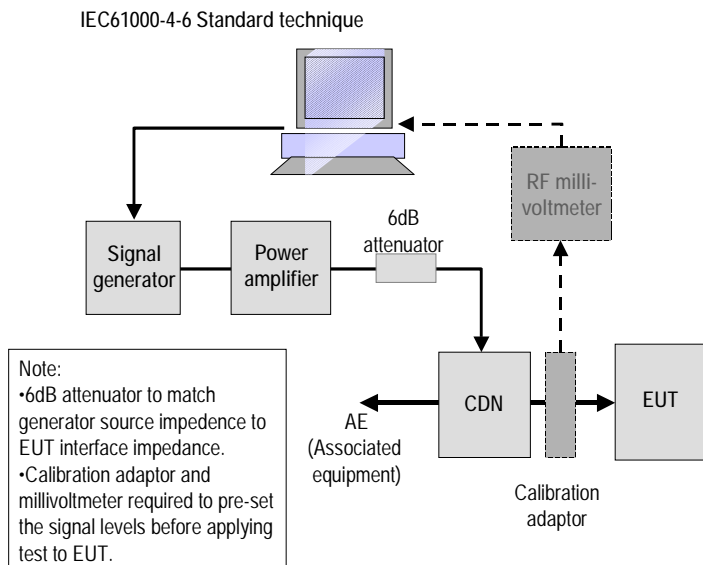


Figure 9. Conventional operation with CDN

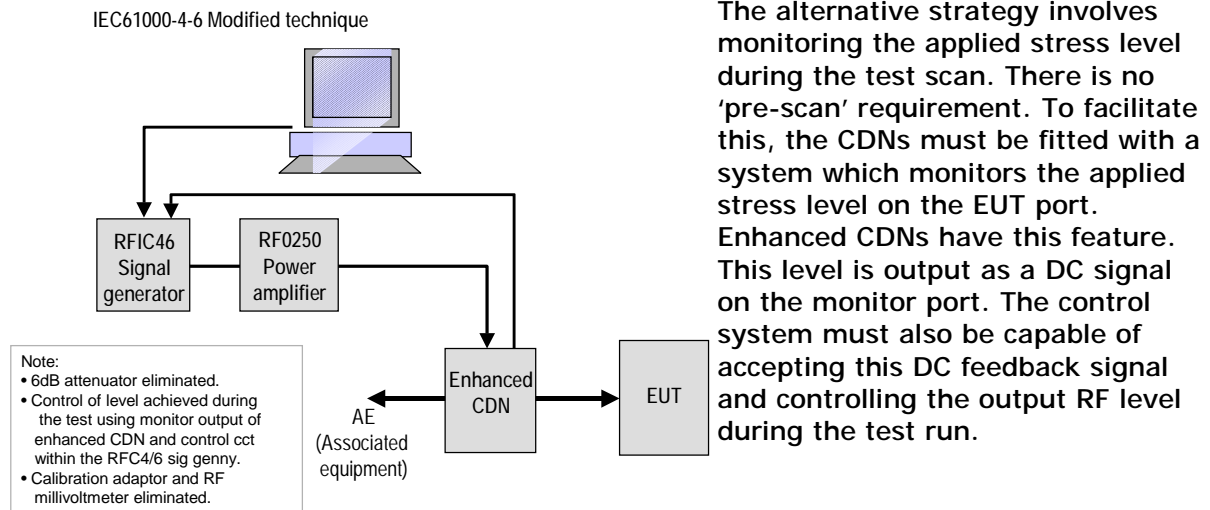


Figure 10. Enhanced operation

Injection Technique

See the choices described in section 2. These are CDN, EMClamp and BCI probe. CDNs are the preferred technique but the other two could be used with the RFIC system. Note that the BCI technique does require higher RF power levels, and these probes may require higher power levels than the 25W offered by the RF0250 power amplifier.

4. Test Setup

CDNs

Figures 11 and 12 show a typical test arrangement.

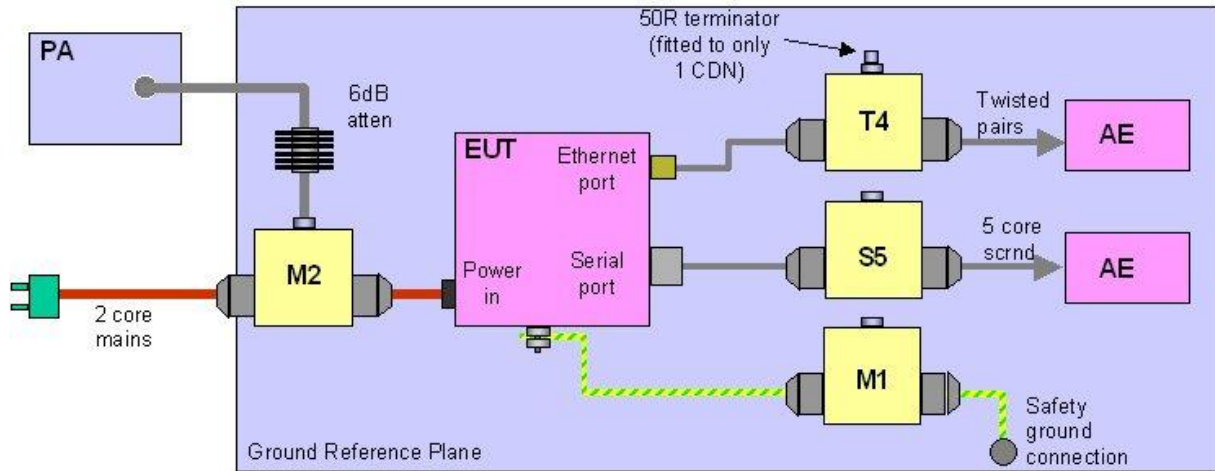


Figure 11. Typical test arrangement—plan view

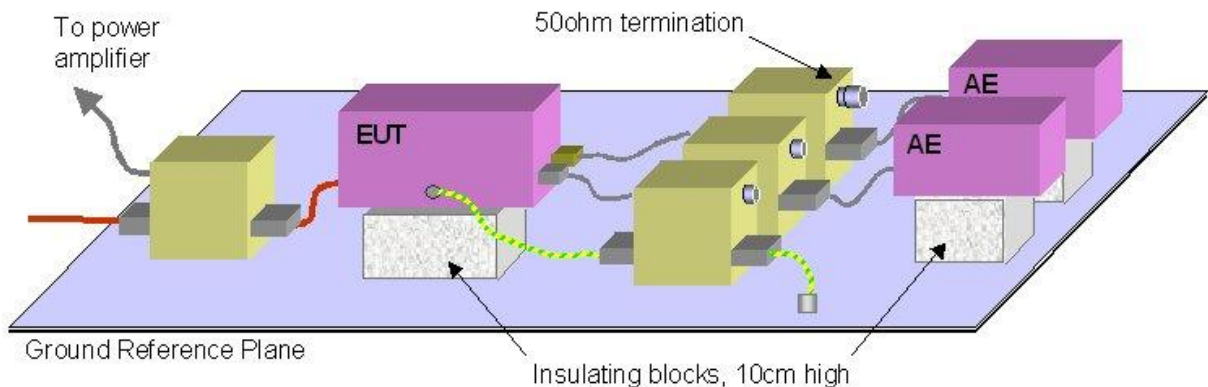


Figure 12. Typical test arrangement—side view

Points to note are:

- All CDNs are firmly bonded to the ground reference plane.
- The stress injection is applied to one cable at a time.
- All other cables are fed through CDNs to maintain the 150R impedance.
- Even the earth point on the EUT (if fitted) is grounded via CDN.
- The EUT and AE are spaced 10cm off the ground plane.
- Just one CDN is fitted with a 50ohm terminator.

Note that each cable is connected via the appropriate CDN. In this instance, if using the Laplace Versatile CDNs, the following models could be used:

Cable type	Conventional CDN	Versatile CDN	Other cables covered by versatile CDN
2 core mains	M2	M3	M1, M3
Ethernet (4 twisted pairs)	T8	T8	T4, T2,
5 core screened	S5	S25	Snn (nn = 1, ... 25)
Earth connection	M1	M3	M2, M3

5. TEST

Set out the test equipment, EUT and AE as described in the previous section. Reference to IEC61000-4-6 is recommended to ensure the arrangements are compliant.

Selecting the injection device and mode

Generally the choice of injection device will have been made according to the constraints of the product and cabling. The key choice may then be test strategy, Conventional or Enhanced. To enter these factors, go to [Main menu... Transducer](#)

A selection screen will be shown, see fig.13...

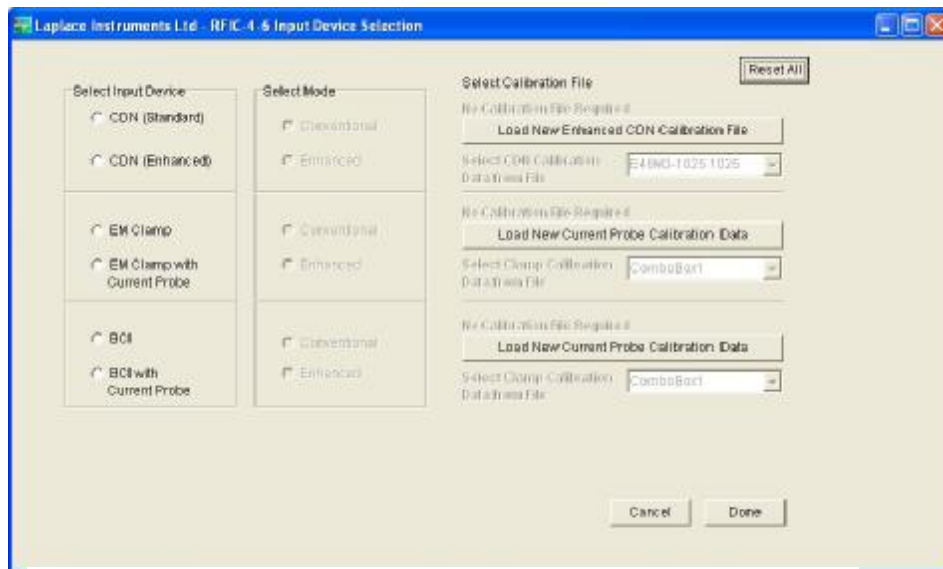


Figure 13. Test setup selection screen

Click on the appropriate input device as listed on the left side.

Once this selection has been entered, the appropriate mode and calibration options will be enabled. For example:

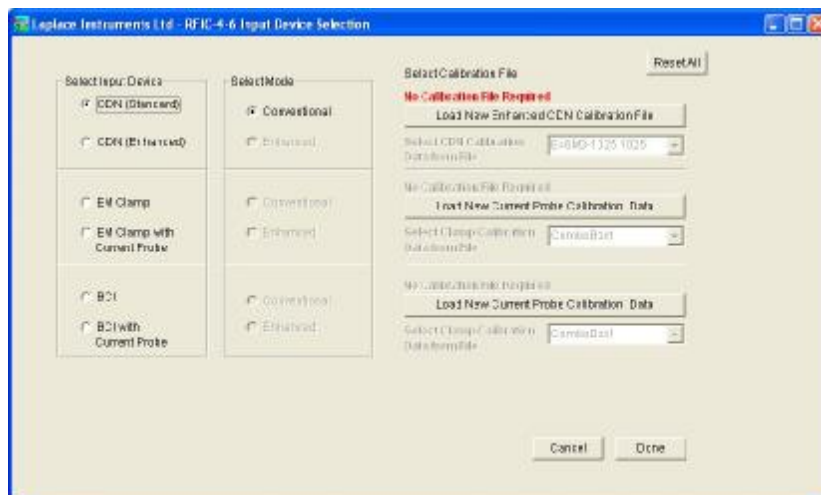


Figure 14. Conventional selection

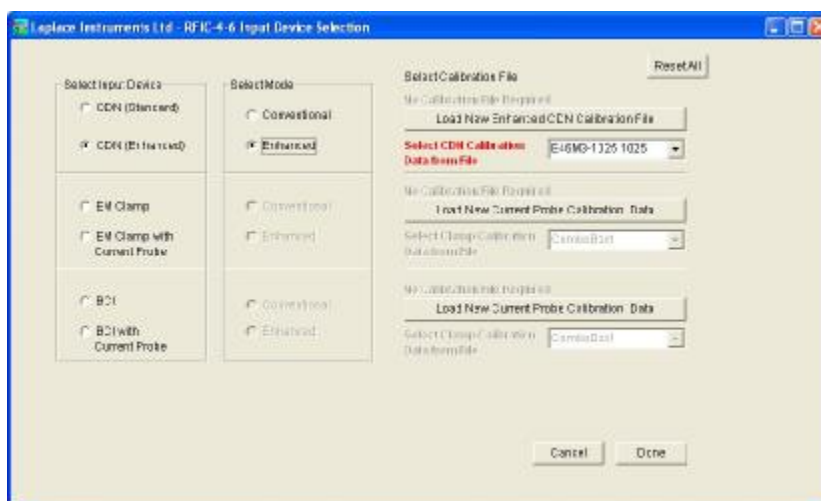
The conventional (standard) CDN has been selected. In this case there are no further choices as this can only be used in the conventional mode and no calibration file is required.

In this next instance, the Enhanced model of CDN is selected. This may be used in a Conventional or Enhanced mode, so both these options are made available.

If 'Enhanced' is selected, the options to select the relevant calibration file, or to load a new file, are available.

If 'Conventional' mode is selected, 'No Cal file required' is highlighted

Selecting 'Enhanced' mode activates the options to load a calibration file or to select one from the existing list. A window is displayed in which any previously loaded CDN can be selected from a list, or a new CDN loaded. A browse feature is included so that the relevant file can be selected from (for example) the CD and installed.



To change the selection, click '**RESET ALL**' and the page will return to its initial state.

Figure 15. Enhanced selection

In order to repeat a previous test (assuming that the test had been 'Saved', the settings, calibration and pre-scan data can be loaded using the [File... Open](#) menu.

Entering the test parameters

First, the type of test can be selected. The choice is 'Standard', 'Custom' and 'Single'. These are selected from the buttons displayed near the bottom of the screen. Note that **Single** is only available in Enhanced mode.

These choices are explained in section 7, page 25. Normally, Standard will be used. Single is only required for investigative work and custom used only when the stress level must be varied with frequency during the test.

Then the Start frequency, Finish frequency, Stress level, Frequency step (the standard specifies 1% or less) and dwell period must be entered in the left hand section. The estimated time for the test is displayed.

In the central section, EUT Status parameters, EUT Prompt and modulation requirements are entered. For most tests, the 1kHz, 80% deep, AM modulation is required.

If EUT monitoring is to be used, select **main Menu... EUT Monitor** to display the monitor settings page. Note that the inputs are 0—10V (100Kohm impedance) and are sampled at approximately 5Hz rate.

Each channel (A...D) can be assigned a name, a colour and have high and low thresholds defined. These should be the limits of acceptable operation during the stress test. Excursions outside these thresholds will be treated as an EUT fail.

Once the EUT monitor inputs are connected, operation can be checked prior to the test with the bargraph display to the right of the selection areas. **Single** will update the measurement once, whilst **continuous** will measure in real time until **Stop** is clicked. The **Reset** button resets the max/min indications.

CONNECTIONS

CDN used in the Conventional mode:

This mode can be used with ANY CDN, including third party and Enhanced CDN.

Prior to testing the EUT, the connections from the CDN to the EUT and the AE are removed and calibration fixtures (type 46ZZ) are plugged into the EUT and AE ports on the CDN. The AE fixture is fitted with a 50ohm terminator and the output from the EUT fixture is connected to the RF feedback port on the RFIC46. The pre-scan is then run over the frequency range required. This automatically adjusts the output level at each frequency step so that the desired stress level is achieved. The software maintains a record of the power levels required.

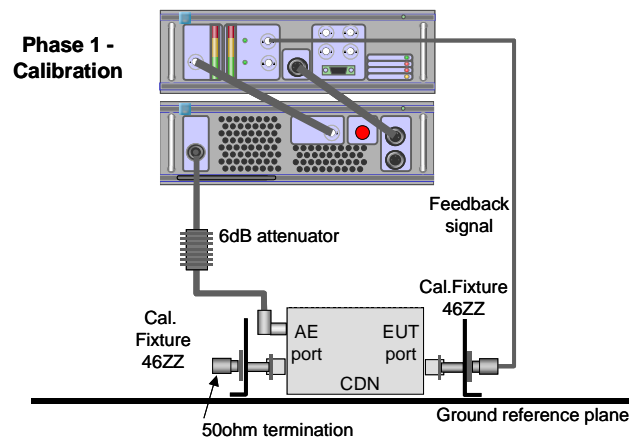


Figure 16. CDN phase 1

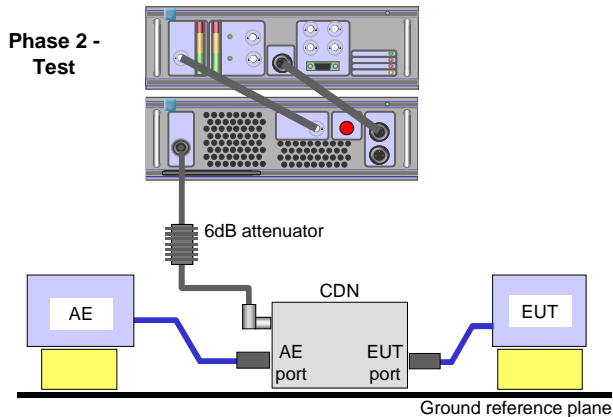


Figure 17. CDN phase 2

Once this pre-scan phase is completed, remove the calibration fixtures, reconnect the cables and run the test. See fig 17.

CDN - Enhanced mode

If using an Enhanced CDN (Model E46xxx) then the test can be accomplished in one phase.

Connect the system as shown in fig 18. Note that the CDN Monitor output is connected to the DC feedback input on the RFIC46 unit.

The calibration file should be entered or selected in the setup/ mode page. Each CDN will have its own calibration file, nnnn.enh.

This test will now run without any pre-scan.

EM Clamp

Conventional Strategy

As with the CDN, there is a 'Calibration' phase then a 'Test' phase. The calibration is performed with the clamp driving into a conductor terminated in 150ohms. The 100ohm in the fixture is supplemented either with a 50ohm terminator or the 50ohm input impedance of the input port on the RFIC46. The arrangement is shown in Fig.19

Note the critical importance of the grounding of the fixtures to the ground plane. Suitable calibration fixtures are available from suppliers of the clamps.

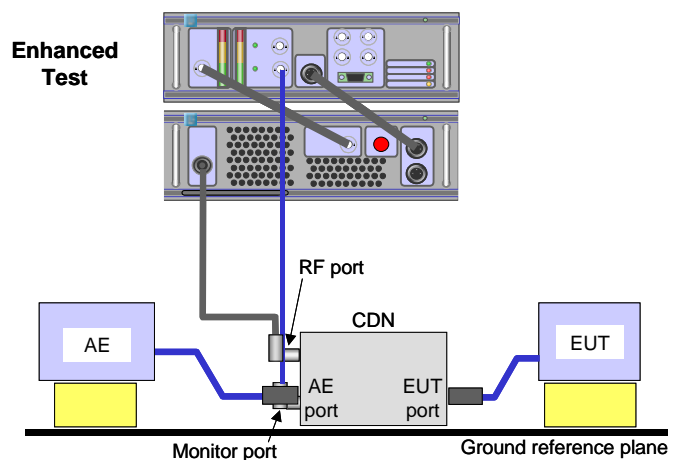


Figure 18. CDN Enhanced mode

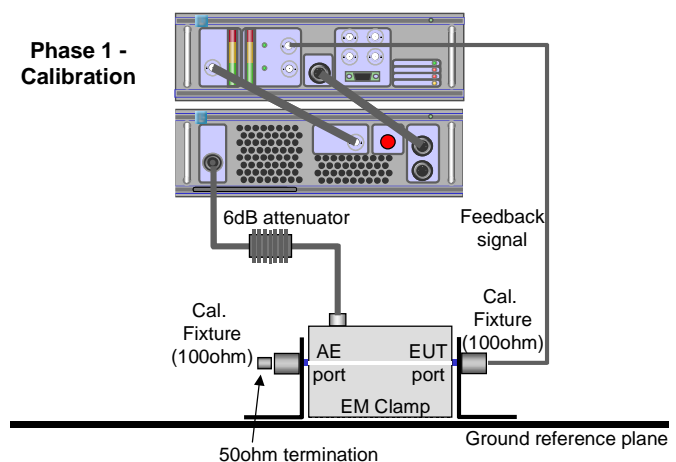


Figure 19. Operation with EM Clamp (1)

Once the calibration phase is completed, the fixtures are removed and the cable to be tested can be installed. Note the requirements for spacing the EUT and AE above the ground plane by 10cm. Cables on the EUT side should be kept as short as possible.

The inclusion of a ferrite clamp on the AE side is recommended as this avoids excessive stressing of the AE and (if the AE has low RF impedance) avoids understressing the EUT.

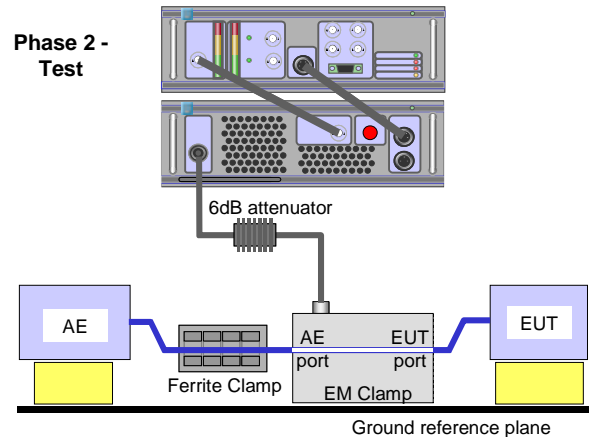


Figure 20. Operation with EM Clamp (2)

Enhanced Strategy

A current probe can be used to provide feedback to the RFIC system during the test. The setup is shown in Fig. 21

The calibration factor for the probe must be entered into the RFSynth software.

This removes the requirement for a pre-scan.

The setup shown could be used connected as shown, after pre-scan phase (phase 1) has been completed as per fig 19. In this instance the system is now running in phase 2 of conventional mode and the current probe is used only as a monitor of the stress level applied, but not used as part of the feedback system.

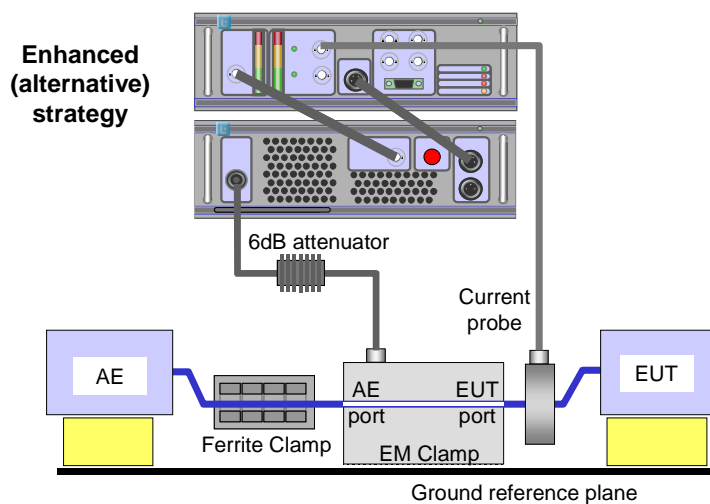


Figure 21. EM Clamp—enhanced

BCI

The preferred technique is now to use the substitution technique, ie a similar strategy to the CDN in 'conventional' mode.

The calibration fixture in this case comprises a conductor terminated at one end with a 50ohm load (of adequate power rating) and the feedback to the RFIC from the other end. Using this setup, the pre-scan is run and then the target cable replaces the calibration fixture and

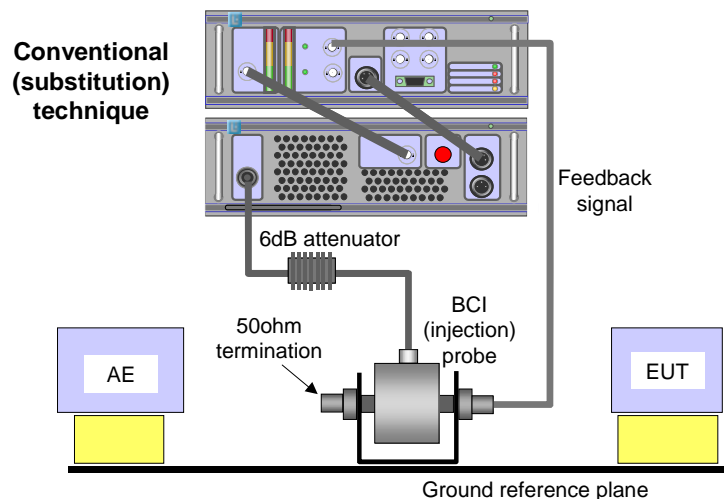


Figure 22. BCI phase 1

the test is run as shown in Phase 2.

The current monitoring probe can be used to display the stress level if required. Note that this is not used for level control feedback.

The system can be used in the Enhanced mode. The calibration data for the monitoring probe should be entered into the software and then the test can be run in one operation. (subject to the cautions explained in section 3).

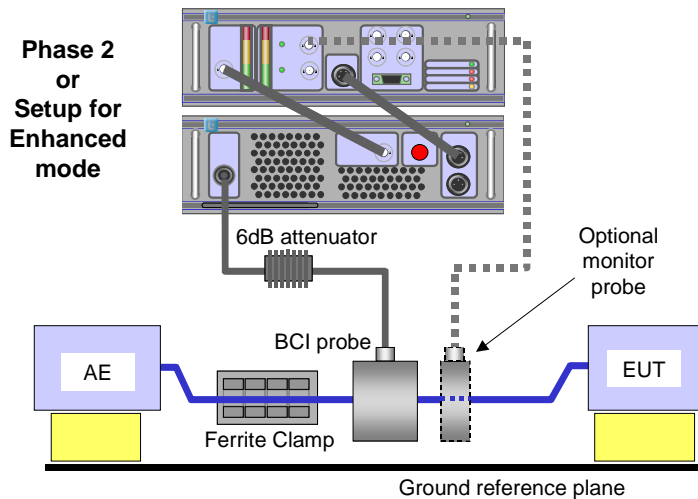


Figure 23. BCI Phase 2

EUT Monitoring

The RFIC46 is equipped with 4 analogue input channels, A, B, C and D. These are all identical. They have a range of 0-10v, input impedance 100Kohm, single ended.

These inputs are sampled at a rate of approx 1Hz during the dwell time at each frequency. The resulting measurements are plotted on the PC screen in graphical and bargraph format.

See section 7 for more details

EUT Prompt.

This facility enables the EUT to be 'prompted' at the start of each dwell period. This is to synchronise any cyclic operation of the EUT with the stepping of the test through the frequency range. If selected in the test setup screen, a 4 pole relay inside the RFIC46 unit operates a 4 pole c/o relay for 1 second at the beginning of each dwell period. The 12 contacts are brought out to the 15 pin D type connector on the front panel.

6. Hardware

The RFIC system comprises 3 elements:

- RFIC46 signal generator and controller
- RF0250 Power amplifier
- CDNs or other injection devices

The RF0250, CDNs and other devices are fully covered by the individual user manuals supplied with each.

RFIC46

This compact unit provides the following functions:

- Signal generator according to IEC61000-4-6.
100KHz—250MHz, -45dBm to 0dBm
- Modulation as required by the standard
1KHz AM @ 80% depth plus pulse modulation, 2Hz, 20Hz & 200Hz
- RF output level control
Automatic levelling using feedback from either feedback input.
- An RF millivoltmeter for monitoring of applied RF stress level
-60dBm to +30dBm
- A DC input for use with Enhanced CDNs
0 – 20v dc, 20mV resolution (10 bit ADC)
- 4 channels of analogue inputs for EUT performance monitoring
0—10v, single ended, 100K input impedance, 10mV resolution
- An EUT prompt system
Volt-free relays contacts
- Safety interlock system for the power amplifier
- USB interface to PC.

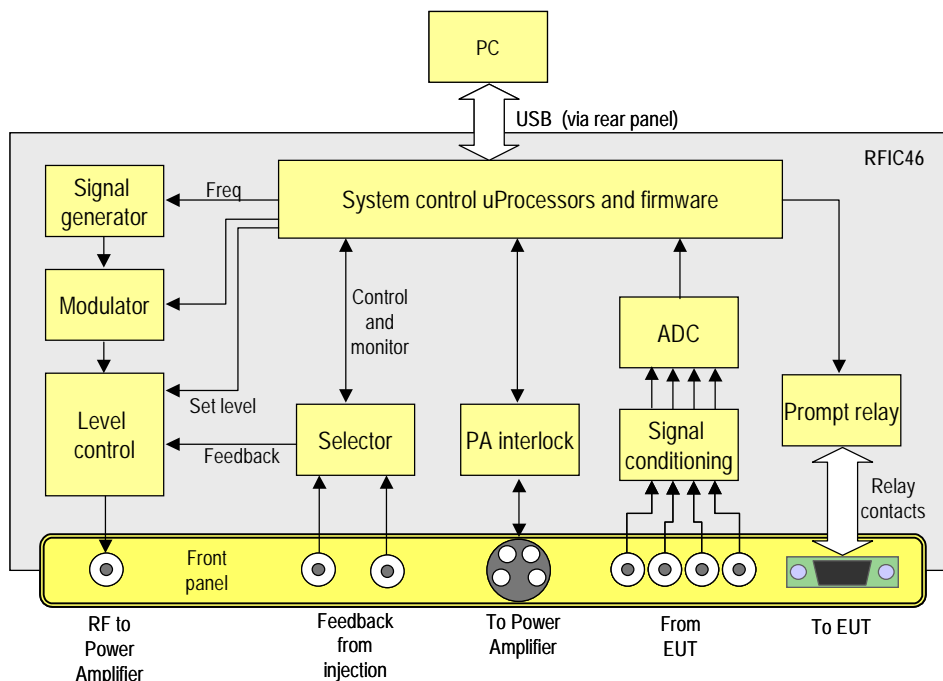


Figure 25. RFIC Block diagram

The block diagram shows the main elements of the systems inside the unit.

Note that the level control system includes an output level monitor to ensure that the output does not exceed the 0dBm limit, thus protecting the power amplifier from overload.

The operation of the RFIC46 is entirely controlled by the RFIC software supplied with the unit. There are no controls on the hardware itself.

Indications

The bargraphs for RF output level and Feedback level are for indication only. These are provided to give an approximate indication of operation of the system. The red levels are simply an indication that the levels are approaching the maximum levels, not an indication of overload. When the feedback is being used for level control, the indications will not generally be equal. This is normal.

The feedback level will be driven by the feedback input that is currently selected, as indicated by the green LEDs adjacent to the input BNC connectors.

Status Indications:

- Standby: RF output is switched off and the system is dormant.
 PA Status: This will indicate if the PA is switched into standby mode.
 EUT Prompt: Prompt relay energised
 Running: System is in 'dwell' mode

Front panel layout

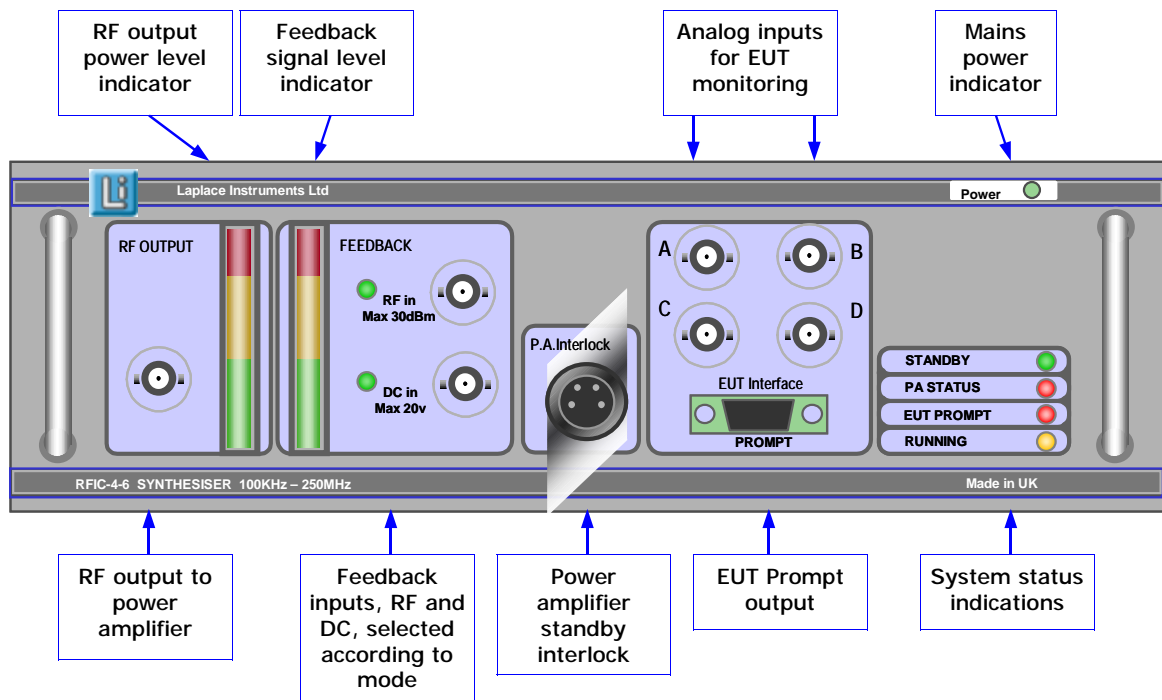


Figure 26. Front panel

Rear panel layout

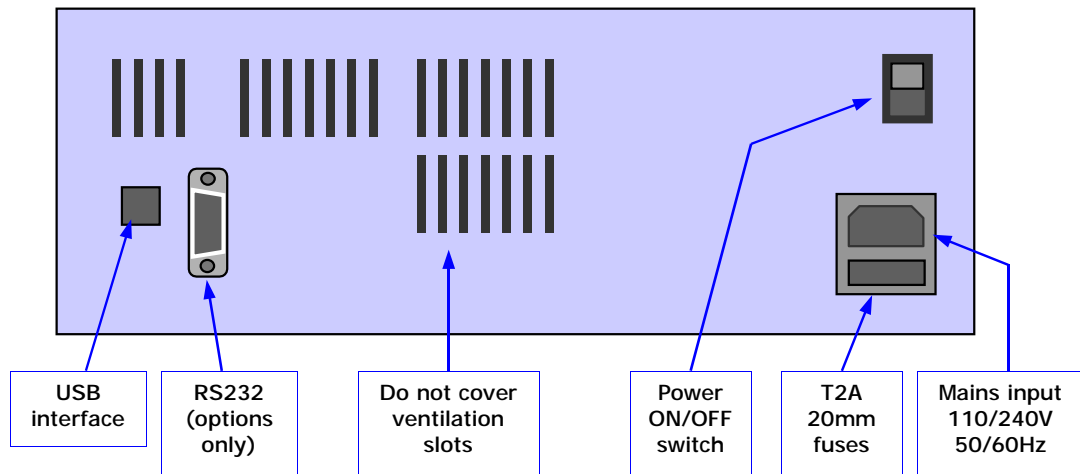


Figure 27. Rear panel

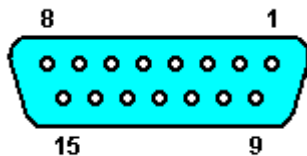
Power: Mains power is applied.

Connections

EUT Prompt

The prompt output from the RF1000 is a 4 pole c/o relay. All the contacts are brought out to a standard 15 way Dee type connector.

Pin numbering



Connection detail

Common	NO	NC
10	1	9
11	3	2
12	7	8
13	15	14

Figure 28. EUT prompt connections

Notes:

- NO contacts are closed when EUT prompt operates
- NC contacts are opened when EUT prompt operates
- Contact rating is 20v rms or 40v dc, 300mA.
- When pulsed prompt is used, contacts close for 1 second at the start of each dwell period.

PA Interlock

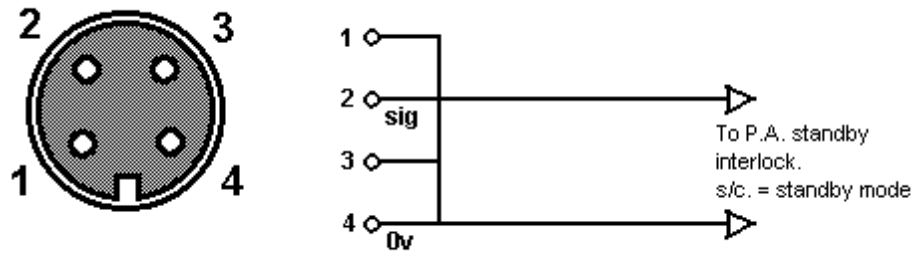


Figure 29. PA interlock connections

The RF0250 power amplifier can be set to standby remotely by the RFIC46, or can be switched locally on the PA front panel, in which case the interlock will report status back to the RFIC system.

7. Software

The RFIC46 is shipped with RF46 software. This software should be loaded onto your PC and will provide all the user interface requirements for IEC61000-4-6 testing.

Installation of the software is described in annex C

The interface between the PC and the RFIC46 synthesiser is via USB bus. Any USB port on the PC may be used. Connect the supplied USB cable between the PC and the synthesiser. (If this is the first time that the PC has 'seen' this synthesiser, it may request details of the relevant driver. See annex C for details).

When the software is run, it will first check that the hardware is connected and switched on. If this is not the case, a warning message will appear. Check the connection and ensure that the hardware is powered up. The software can be used without the hardware for display of results and producing hardcopy. In this case just accept the warning and continue.

Once the software is running, the main screen will be displayed. Note that the settings will match those that applied when the software was last used.

The main screen comprises 5 areas.... (see figure 30).

Status area.	A
Main menu bar	B
Operating controls	C
Monitor area	D

And
The main setup and results display area E

This area E will switch between modes, according to the users requirements. These modes are:

Setup controls (E1 and E2):

- Standard settings
- Custom settings
- Single point settings

Monitoring screens: (E3)

- Chart showing all parameters of the test in real time
- Bargraph display of EUT monitor channels

Details.

Area A

Status

Indicators show the status of the hardware:

Ready:	System OK and operational
Running:	Test running in 'dwell' mode
Settling:	System adjusting the stress level to the required level
Modulation:	Modulation running
Standby:	System in standby mode. RF output switched off.

EUT

OK	No EUT fail detected
Fail	EUT failure detected
Prompt	EUT prompt activated

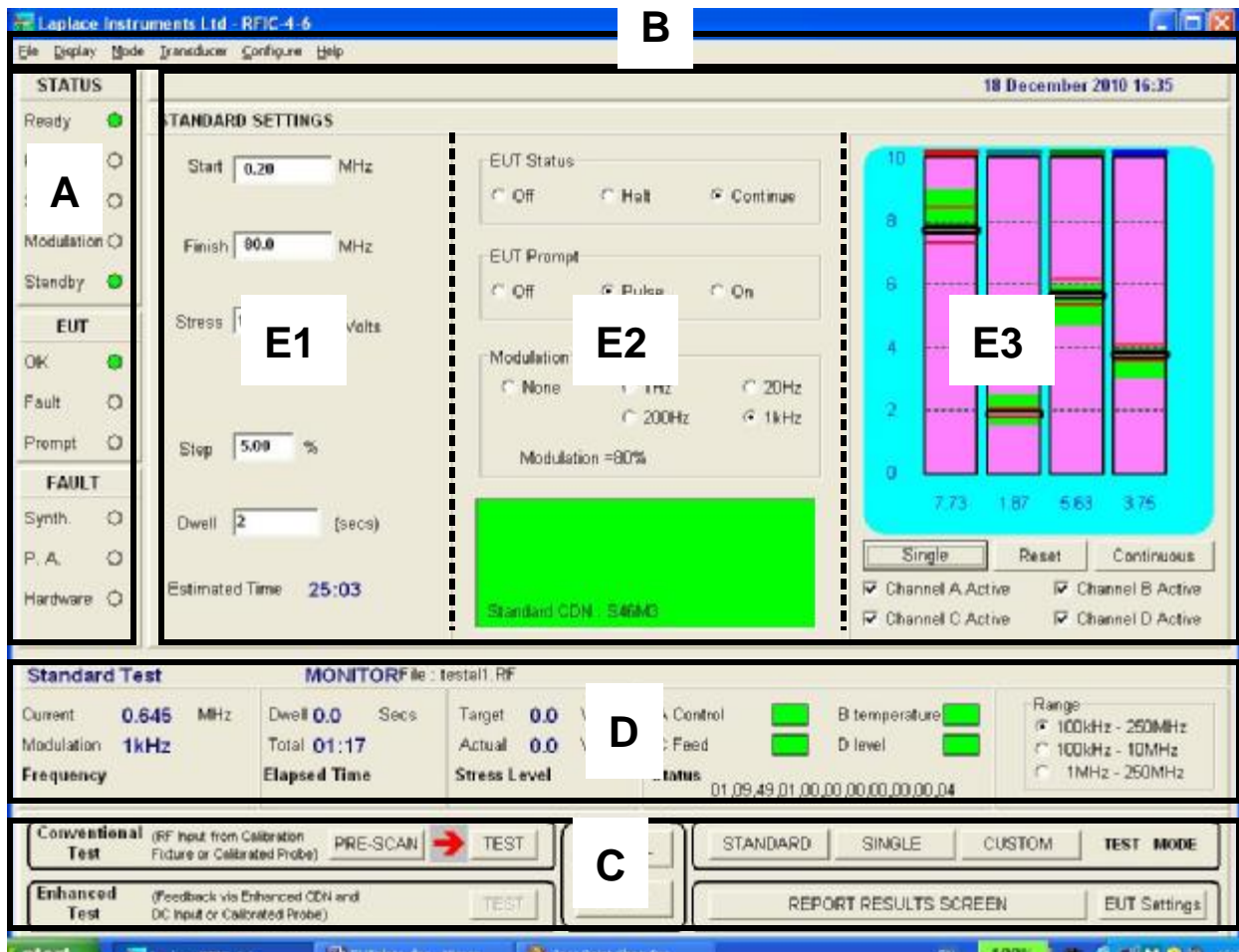


Figure 30 Key screen composition

NOTE: Section E will change according to the mode of operation that is currently selected. These modes relate to either setup information or display of test results.

FAULT

Synth Synthesiser responding abnormally.
 PA Power amplifier fault detected
 Hardware Comms problem. If this occurs, a Re-connect button will be available.

Area B Main Menu bar

File Storage and retrieval of results and setups, plus
 Printing options.
 Display Colour and formatting options
 Mode: Operating modes (Standard Settings, Custom and Single)
 Transducer Select injection device and test mode
 Configure Check USB, install CDNs, define EUT monitor inputs
 Help

Area C Operating controls

These are the controls that initiate test sequences and which select the test mode (Standard, Single and Custom) and screen mode as shown in screen section E. [EUT Settings](#) button shows the screen where the EUT monitoring parameters can be set.

Area D Monitor Section

This shows the current status of the test. It includes current frequency and stress level, type of modulation and elapsed time (current dwell time and total elapsed time). Also shown are the status of the EUT monitoring channels and a selector for the frequency range shown on the Results page.

Area E Setup and EUT monitor

This section has 3 sub sections, E1, E2 and E3.

E1 is the frequency setup information. Start, stop, frequency step and dwell time are entered here. It will change according to the test mode selected in area C. The choices are Standard, Custom and Single.

Standard: Enter parameters for a standard sweep with a fixed stress level for the whole test.

Custom: This enables the stress level to be changed during the scan. The required parameters can be entered as nodes in the table. The software will automatically interpolate between nodes.

Single: (Only available in Enhanced mode) Frequency and stress level can be entered and these parameters 'nudged' up and down in increments entered in the Inc. fields.

An auto Increase feature can be selected which will automatically gradually increase the stress level in increments set in the Level Step inc. field, until End Level is reached, or the EUT fails.

E2 remains the same for all setup modes. It enables selection of EUT status interaction, EUT prompt activity, modulation selection and an activity area.

E3 displays the 4 channels of EUT monitor inputs in bargraph format.

During a test, Area E can be switched to show a chart format ([Report Results Screen](#)) which shows the target stress level, the actual achieved level and the EUT monitor channel results, all plotted against frequency in real time..

Operation

In this section, operation with CDNs is assumed as this is the preferred technique according to the standard. The operation with EM Clamps or BCI probes is very similar... same connections (unless otherwise indicated) and procedures.

See section 4 for the preparation of the test equipment and the selection of the injection device and mode in the software. It is assumed that these choices and settings have been entered in the selection screens shown in fig 13.

Conventional strategy

Phase 1 Pre-scan

Connect the system as shown in figure 31

Take care to arrange the setup correctly as described earlier and in the standard IEC61000-4-6.

Both the AE and EUT ports on the CDN are connected to calibration fixtures. The output from the EUT side is connected to the RF feedback input on the RFIC46.

The AE calibration fixture must be fitted with a 50ohm termination.

On the control screen, under the **Transducer** item in the main menu (Section B) enter the serial number and parameters of the CDN which will be used for the stress injection.

Then enter in section E1:

- start frequency
- finish frequency,
- stress level
- step size
- dwell time

The screen will provide an estimate of the total test time.

In section E2, enter

- EUT status mode,
- EUT prompt mode,
- modulation

To see the setting graphically, click on **Report Results Screen** (section C). The screen will show a plot of the target stress level against frequency.

If all is now ready, Click **PRE_SCAN**.

The system will commence the calibration scan. Progress can be observed on the 2 bargraph displays on the RFIC46 front panel. These give an indication of RF output level and feedback signal level. These are for indication only and will not generally be equal in level.

Section D will show actual and target levels achieved.

The Pre-scan will not include any dwell periods as there is no product to stress, thus saving time.

Once the Pre-scan is completed, the pre-scan settings can be saved to disk if for later use if required. Note that if this is done, any future use of this file must be done with care, ensuring that the test setup is exactly replicated.

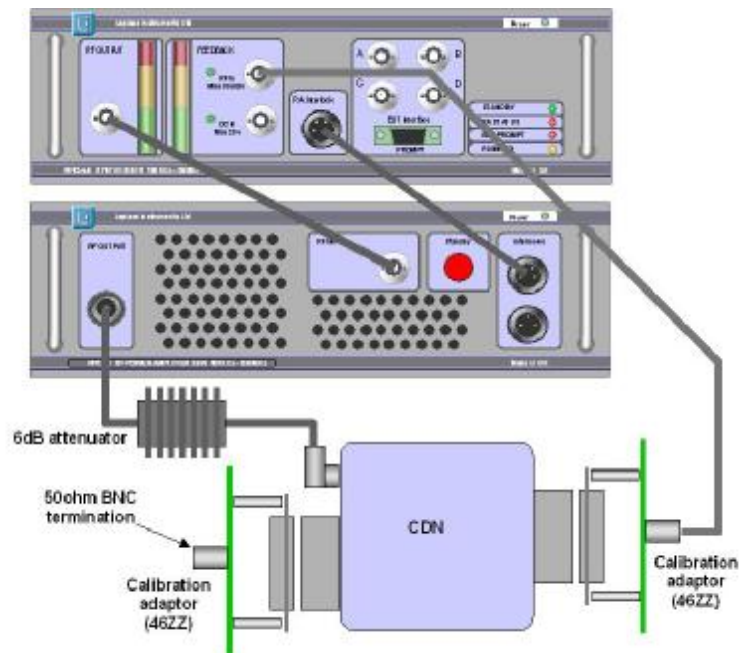


Fig 31. Phase 1 of conventional technique—Pre-scan

Phase 2 - Test

The calibration fixtures can now be removed and the EUT cables connected to the CDN. See fig 32.

Any EUT monitoring inputs should be connected and checked for operation. See later in this section.

The **TEST** button will now commence the EUT test, using the power settings stored during the pre-scan phase. As there are no feedback inputs at this stage, the feedback level indicator will be dormant. (although, if using an enhanced CDN in 'Conventional' mode, the monitor output on the CDN can be connected to the DC feedback input on the RFIC46 and the stress level can be monitored on the bargraph and on the results screen. This level is not used for level control purposes).

The EUT status inputs are plotted on the PC screen and any deviations outside the pre-set thresholds will be classed as a failure. The response of the system to a failure will be as prescribed by the user in the setup screen E2.

Conventional mode, using EM Clamp or BCI probe.

The procedure will be as described for the CDN above, except that the calibration fixtures will be appropriate for the injection device used. Ensure that the correct device is selected in the main setup screen because the feedback levels are calculated differently according to whether it is an EM Clamp or BCI probe fitted.

Enhanced Mode

The Enhanced CDNs are designed to feedback the applied stress level as input to the CDN, **Not** the level actually applied to the EUT cable. This is closer to the requirements of IEC61000-4-6 in which the pre-scan levels ignore the effect of the EUT cable.

Using Enhanced mode with EM Clamps and BCI probes with the feedback obtained from a current probe will be less compliant with the standard. This is because although this technique delivers a more stable stress injection, it does not allow for the effect of the EUT input impedance. (See section 3).

However, the RFIC system does allow for enhanced mode to be used with all types of injection device, but the CDN is preferred as this is the only one specifically designed for this mode.

Connect the system as indicated in fig 18.

Select the appropriate injection device and mode in the [Main menu ...Transducer](#)

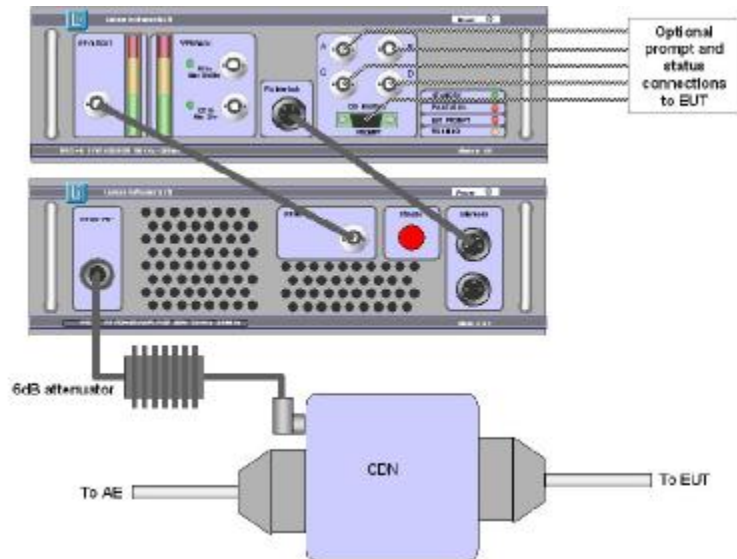


Fig 32. Phase 2 of conventional technique—Test

screen. The calibration data for the relevant device must be entered.

Once the EUT is fully connected and operating normally in the required mode, the test can commence. Click the Enhanced Test **RUN** button.

The progress of the test can be monitored on the RESULTS screen and on the MONITOR screen.

When the test is completed, the test data can be saved to file using the File... Save menu. This will save the setup information, the actual stress level data and the EUT monitor results.

Scan Modes

The RFIC system has three modes for running the test in terms of frequency and stress level.

Mode	Details
Standard	Steps through the specified frequency range from start to finish frequency with a fixed stress level. Step size and dwell time are user selected.
Single	Applies the stress at a single frequency. The frequency and/or stress level can be entered manually, or can be stepped in pre-set increments using Up/Down nudge buttons.. In addition, an 'Auto-Increase' mode can be selected in which the stress level can be automatically incremented after a specified dwell period. This can be set to stop when an EUT failure is detected. Note that this mode cannot be used in Conventional mode.
Custom	Similar to Standard, except that the stress level can be varied against frequency. Data Entry is via a table in which key nodes are entered. The software will automatically interpolate between nodes.

EUT monitoring

There are 4 channels of analogue inputs available. Each is a 0—10v input.

To configure these inputs, select **Configure... EUT input setup** from the main menu. The window shown in fig 33 will be displayed.

Each channel can be given a name, a colour and high and low limit thresholds.

All parameters are scaled 0—10 corresponding to the input voltage.

Any excursion outside the limits will be treated by the software as an EUT failure. The action on 'EUT Failure' is defined by the user in Fig 30, section E2.

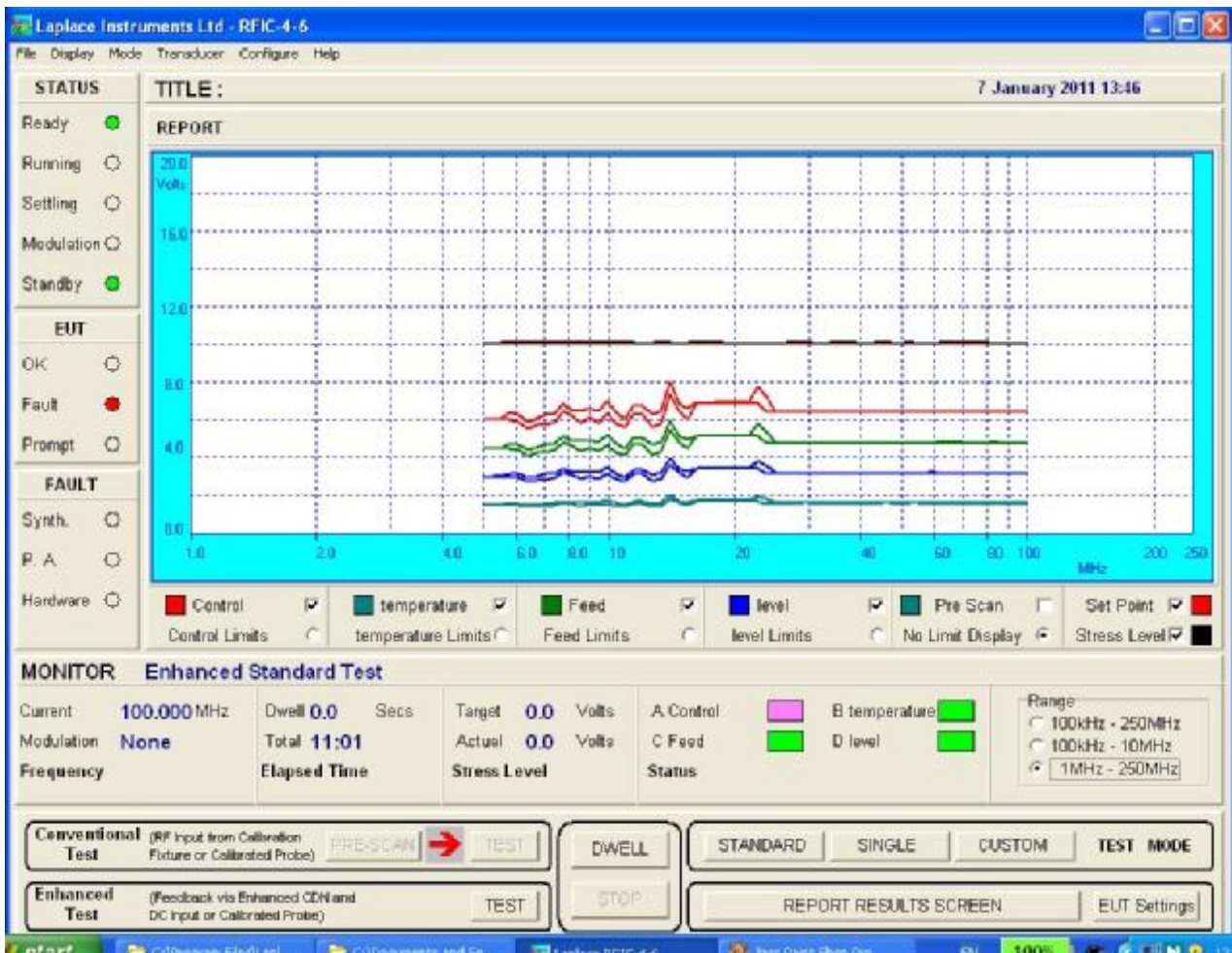
The screenshot shows the 'EUT Settings' window with the following data:

Name	Low Limit	High Limit	Display Colour
Control	2.000	3.000	Red
temperature	2.000	7.000	Teal
Feed	5.000	8.000	Green
level	7.000	9.000	Blue

Additional controls include a 'Limit Colour' button with a red color swatch and an 'Accept Data Change' button at the bottom.

Fig 33. EUT monitor setup screen

The inputs can be checked by using the **Single** button in area E3 on the main screen. This will display the current values of the input channels. Once a test is in progress, these inputs can be plotted on the Results page available by clicking on the **REPORT RESULTS SCREEN** button.



On this screen the following parameters can be observed by clicking on the tick boxes across the bottom of the graph area....

- Set point (stress level)
- Actual stress level. This shows the measured values during an enhanced test. If a conventional test, then this shows the values obtained during the pre-scan.
- EUT monitor levels
- EUT monitor limit levels

In addition, the Monitor area provides readouts of the frequency, actual stress level, timing and EUT status (OK or Fail).

The above screen shows the 4 analogue input channels plotted. Note that each channel may show as 2 lines. These represent the max and minimum measured values during each dwell period. So if an input varies widely due to noise or instability, the effects can be clearly seen.

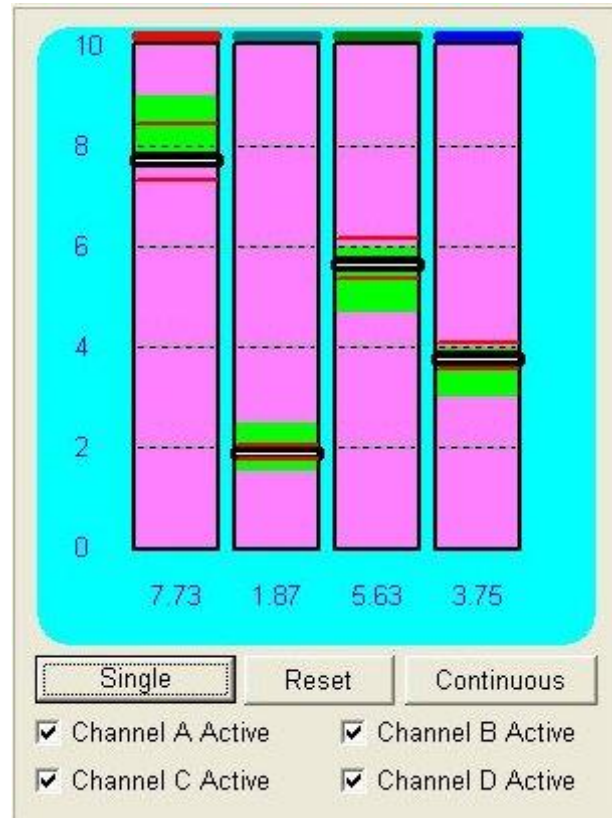
The straight lines at 10V indicate the set level and the achieved level.

Within the main control screen (E3), the state of the EUT inputs can be monitored on a bargraph display. This shows all 4 inputs, together with the thresholds shown as background colour. This display is updated continuously during a sweep, showing the max and minimum measurements during a dwell period, so that all excursions can be observed.

The thick black line is the current reading, the white centre shows the precise value. The thin red lines are the maximum and minimum readings during the test.

The red and green background bands show the thresholds of the high/low limits.

The [Reset](#) button will reset the max and min memory.



ANNEX

Annex A: Best practice.

Annex B: Shipping list

Annex C: Software installation

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Annex A: Pitfalls and practice of IEC 61000-4-6 conducted immunity testing

By Tim Williams, Elmac Services and Richard Marshall, Richard Marshall Ltd

Introduction

IEC 61000-4-6 is widely used for compliance testing of RF immunity of apparatus for the EMC and R&TTE Directives. It applies an RF stress over the frequency range 150kHz–80MHz to the cables connected to the equipment under test (EUT) to determine its immunity to this stress.

The principle of the test is to excite both electric and magnetic disturbance fields within the EUT by applying the stress in common mode with respect to the ground reference plane

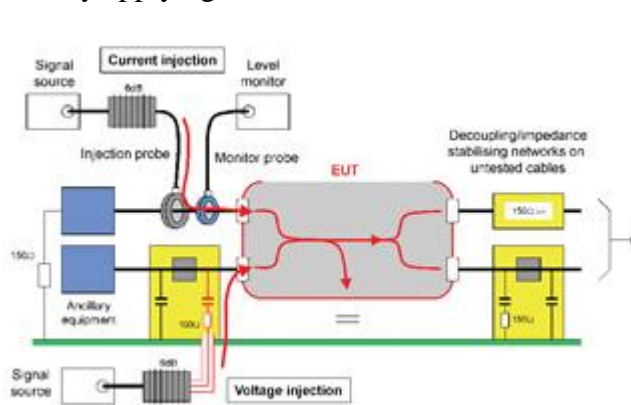


Figure 1 Principle of conducted immunity testing (according to the first edition)

(GRP) to certain selected cables entering it (Figure 1). The stress is applied through a defined source impedance of 150Ω , which is also taken to be the impedance of other cables connected to the EUT. Therefore we must use networks to stabilise this impedance or to decouple it, so as to ensure that unwanted variations have little effect on the test; and also make sure that the layout of the test is controlled so that variations due to stray coupling are minimised. Clause 7 of the standard covers these issues.

The second edition

IEC 61000-4-6 has recently been republished in its second edition [4], although at the time of writing this has not yet been published in Europe as an EN. There are numerous changes from the first edition, ranging from merely editorial to fundamental changes in the method, and anyone who is familiar only with the first edition will need to revisit the standard to upgrade themselves. One of the most important changes is the move from multiple 150Ω terminations to only a single one. Conceptually, we can imagine the tests applying to a range of different products (Figure 2):

- (a) simple mains-powered apparatus with no other signal or power connections, e.g. household appliances: RF returns only through stray capacitance to the ground plane (remember that the RF is applied in common mode to L, N and E together with respect to the ground plane)
- (b) mains or DC powered apparatus with one other signal or power port, e.g. power supplies, some instrumentation: RF returns through stray capacitance and through the untested but terminated port
- (c) apparatus with more than two ports for power and signal, e.g. most IT equipment: RF returns through stray capacitance and all untested but terminated ports

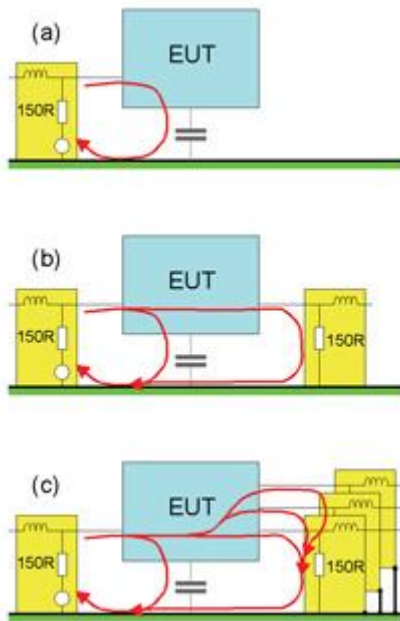


Figure 2 Terminating different types of EUT

The issue here is whether in the third case above, more than one untested port needs to be terminated. The first edition Figure 9 shows that “all non-excited Coupling-Decoupling Network (CDN) ports shall be terminated by 50Ω loads”, implying a 150Ω termination for each cable, so that potentially the RF return path could have a low impedance if several terminated CDNs are used. In the second edition, this has been changed to insist that “in any one test, only two 150Ω networks are required ... one CDN shall be connected to the port to be tested and one CDN with 50Ω termination shall be connected to another port. Decoupling networks shall be installed on all other ports to which cables are attached. In this manner there is only one loop terminated with 150Ω at each end.” (new 7.1.2, 7.2).

This change will mostly affect small multi-port devices, since the untested but terminated port will now be the only one passing RF current out of the EUT. All other ports are decoupled but not terminated. The change will *increase* the

capacitively-coupled voltage stress and *decrease* the magnetically coupled current influence. Decoupling networks just provide a high series impedance; they are usually clamp-on ferrite absorbers, but you have to be sure you are using an absorber which has a high impedance down to 150kHz. This is not an everyday item, even in an EMC test lab, although it is possible to build or otherwise procure one [2].

For a large EUT in a metallic enclosure the changed method of the second edition will make little difference since the capacitance to ground of the EUT will typically be sufficient to bypass current away from the non-excited ports.

Choice of transducers

The standard allows three methods for injecting the stress, and assumes that results from each will be equivalent, although it is now stated that the CDN method is preferred:

- CDN (including direct injection)
- EM-Clamp
- Current probe

This paper discusses the pros and cons, as well as the precautions to take for best practice, for each method. It refers throughout to the second edition for relevant paragraphs, although where this has made changes, the first edition is also quoted.

CDN

The Coupling-Decoupling Network (CDN) is designed to couple the disturbance signal directly to the EUT cable while at the same time preventing it from passing towards the AE (associated or auxiliary equipment). It must also provide a fixed common mode source



Figure 3 shows the schematic of a CDN for a mains three-wire (M3) circuit. It comprises an assembly of a multi-turn common-mode choke for insertion in series with the EUT cable, together with shunt rf filter capacitors **CD** on the AE side and injection coupling components on the EUT side. In general, if there are n wires then each is coupled to the tester via an equal resistor of value nR ohms with an appropriate blocking capacitor **CC** in series. R is 100Ω in the standard specification.

impedance towards the EUT. The discrete components allow a more compact assembly than the other transducers to be discussed; in the assembly shown above the EUT and AE connections are at the top and bottom respectively of the picture and the rf injection is to the BNC connector on the left.

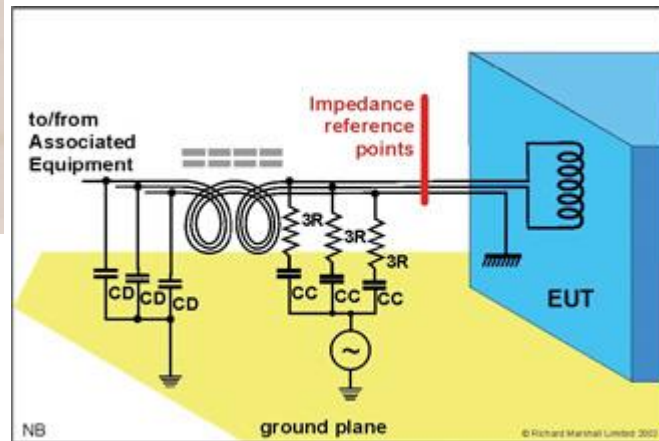


Figure 3 An “M3” Coupling-Decoupling Network schematic

Advantages

- Its prime advantages are near-perfect decoupling of the AE and low uncertainty of the applied stress.
- Minimal power is required and there is minimal radiation or environmental influence.
- Additionally it defines a 150Ω common-mode cable impedance, formed from the 50Ω generator impedance in series with 100Ω resulting from the injection resistors in parallel. This impedance damps cable resonance to increase the repeatability of the test and approximates to real-life, giving a very credible test.

Disadvantages

- It is invasive, that is it requires an electrical connection to the cable shield if there is one, or to each core of an unshielded cable. Accordingly different networks are required for different cables, increasing the capital investment required for general test house use.
- This disadvantage has been partially overcome by versatile CDNs [6] in which a variety of CDN configurations can be achieved by patching links within the AE and EUT connectors. The CDN pictured here may properly be used with coaxial and shielded cables of 1 to 6 cores, and with unshielded cables of 1,2,3 and 6 cores.
- Serious errors may result if an ordinary CDN is used with fewer than its intended number of wires, such as for instance using an M3 CDN for a mains port with only live and neutral. The reasons for this are set out below under “CDN Cautions”.

CDN Cautions

The standard for the CDN only specifies its common-mode impedance. The coupling between the individual conductors is not specified. This leaves the choice and arrangement of the ferrite cores and the construction of the winding entirely to the test equipment manufacturer. Consequently a variety of solutions are in use that meet the common-mode requirements but have varying differential-mode characteristics.

Leakage inductance and transmission-line resonance within the choke are both important but unspecified sources of error since both effects allow the individual wires through the CDN to exhibit individual impedances – that is they may carry different rf voltages if the circuit conditions allow. This may be understood from Figure 3, where the EUT has an isolated transformer winding connected to two wires of its mains cable, whilst its chassis – and hence most of its circuitry and any other cables – is connected to the third. The impedance seen looking into the EUT from the CDN at the reference points is quite high for the upper two wires, being dominated by the effect of the stray capacitance of the transformer winding to its surroundings. The impedance of the lower (ground) wire may be very low, being dependent upon the capacitance from the EUT to the ground plane below, and on any other cables connected to the EUT (but not shown on this simplified drawing). If the CDN's isolating inductor comprised three un-coupled chokes then because of the source resistors $3R$ the immunity test voltage injected into the EUT would clearly be much higher on the upper two wires than on the lower one. Unless the multi-wire choke acts as an effective transformer to equalise the voltages on these three wires there will be transducer errors – but if the choke were perfect in this respect then much less intrusive CDNs could have been specified in the immunity standard which used only transformer action and a primary circuit with a single injection resistor.

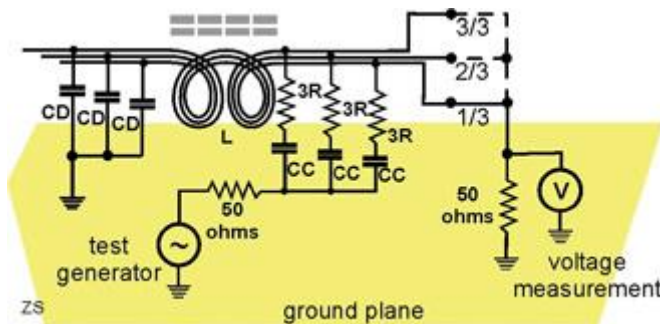


Figure 4 Test of a CDN with an unbalanced load

The magnitude of this effect with commercially available CDNs can be measured with the test set-up of Figure 4, in which the desired selection of the CDN EUT wires – 1 of 3, 2 of 3 or all 3 of 3 – are connected to the input of a spectrum analyser, and the CDN is driven from the output of the tracking generator. If the transformer action of the common-mode choke were perfect then we would expect the same voltage measurement in each case.

Figures 5 and 6 show how the output varies with frequency for two different implementations of the standard M3 3-wire CDN. In each chart the “0dB” ordinate represents the theoretical loss of a 100Ω resistor between a 50Ω source and a 50Ω load. The dotted “3 of 3” plots represent the uniform loading of the wires as envisaged in the standard and show less than 1dB of additional loss which would be partially calibrated out by the normal calibration set up with a 150 load. The “1 of 3” lines in each case correspond to only one wire being connected to the analyser.

That plotted in Figure 5 exhibits a fall of 5 to 6dB over a wide range of frequencies around 15 and 50MHz, whilst that in Figure 6 shows a 9dB fall in coupling in a narrow frequency

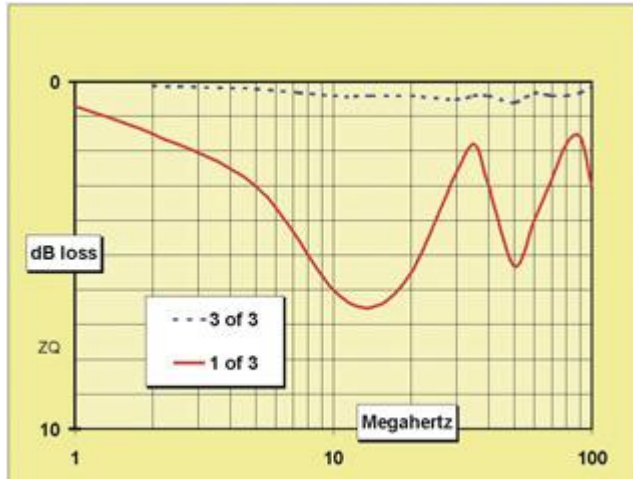


Figure 5 Loss through M3 CDN "B"

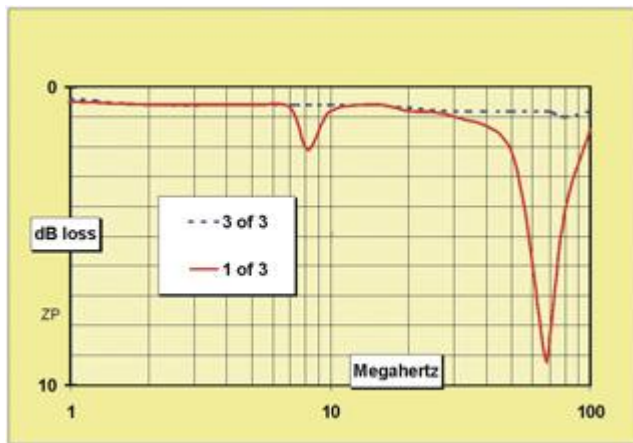


Figure 6 Loss through M3 CDN "A" with unbalanced load

range at about 67MHz.

In CDN "B" the wires occupied separate sections of the core perimeter. The resulting large leakage inductance resonates with stray capacitances but is damped by the core losses producing the broad resonance bands that may be seen in Figure 5.

In contrast, CDN "A" embodied a choke constructed with its three wires twisted together before winding. This minimises leakage inductance – but there is still a narrow-band resonance at 67MHz at which the wire being measured is almost totally disconnected from the other two wires. It can only "see" its own 3R injection resistor. At this frequency the length of the wires that form the CDN choke is an electrical quarter-wave. The wires are short-circuited to rf at the AE end by the capacitors **CD** (see Figures 3 or 4). This short-circuit is transformed by the quarter-wavelength into a very high mutual impedance at the EUT end. This is purely a differential-mode effect in which the ferrite choke core plays no magnetic part.

The "Q" factor of the resonance is high since the only losses involved are those of the dielectrics surrounding the wire and within the capacitors **CD**.

As stated above both these CDNs work well when the EUT circuits offer the same impedance to each wire but give unquantifiable errors in other cases. We have taken as an example the case of the 3-wire mains lead, but other important cases are process control cables with varied circuits within the same cable, and 4-pair data circuits such as "Cat.5 UTP" where some pairs are used for balanced data and the remaining wires are either used for unbalanced power or not used at all.

There are only two CDN design solutions to this problem; the length of wire in the choke must be short enough to push the resonance above the maximum frequency of test, or the resonance must be damped by introducing extra resistive impedance at the AE end.

A reduced length of wire is possible for some varieties of low-power CDNs but since IEC 61000-4-6 edition 2 Annex B extends the common mode impedance specification from 80MHz to 230MHz the scope for this method is now limited.

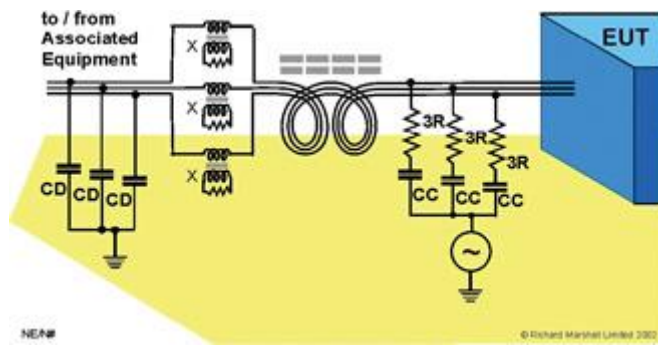


Figure 7 Resistors X provide damping of transmission-line resonance in a CDN

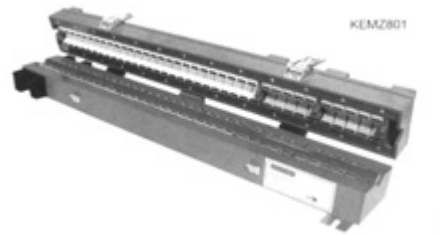
Damped-resonance CDNs are available [3] for the particularly difficult high-current applications where the choke must be a physically large component. Damping is achieved by resistors that are transformer coupled to the *individual* choke wires as may be seen in Figure 7.

Note that the damping components **X** are applied at the AE end of the transmission line choke adjacent to the rf short-circuits provided at **CD**. At this point rf current is highest and the damping resistors will

have greatest influence. Because the coupling between the wires of the main choke is now much more effective, this solution does allow a single CDN to serve almost any conceivable ac or dc single phase or three phase application up to 100 amps with or without associated voltage or control circuits, overcoming for power applications all the disadvantages of CDNs listed earlier.

EM-Clamp

The EM-clamp is a clamping device that subjects the cable under test to both capacitive and inductive coupling of the RF stress. It was invented largely for this test by Bersier and Ryser at the Swiss PTT.



Advantages

- Its principal advantage is that it is entirely non-invasive. No connection need be made to the cable under test.
- Its second main advantage is that it allows adequate decoupling of the AE at high frequencies. The design is arranged so that the capacitive and inductive coupling paths reinforce one another at the EUT end, and cancel at the AE end. This gives the clamp about 10-15dB of directivity above 10MHz.
- Thirdly, it is reasonably power-efficient, although not as good as a CDN; for the same stress, about 6dB more power is needed.

Disadvantages

- Because it uses a series of ferrite sleeves to provide the inductive coupling, it is quite long, and to provide good capacitive coupling it has a relatively narrow inside diameter. This makes it bulky to use and restricts its application for short or large-diameter cables.
- Below 10MHz its directivity is negligible and therefore the AE low frequency common mode impedance is not decoupled.
- It does not provide an accurate source impedance of 150Ω across the frequency range.

Current injection probe

The current injection probe (or Bulk Current Injection, BCI, probe) was not part of the original method but was added before the standard was published at the insistence of several laboratories who were already using it for military standard tests. It acts as a current transformer whose secondary is the cable under test; it provides inductive injection only.



Advantages

- Its main advantage, and the reason it is widely used by many labs, is that it is both convenient and non-invasive. Because it is compact and can be made with quite a wide aperture, it can be used on virtually any cable, even short runs with limited access. This makes it the transducer of choice for in-situ tests.

Disadvantages

- Balancing this practical advantage are several technical failings. There is absolutely no decoupling of the AE, since the current induced on the cable must flow both into the EUT and the AE. Therefore the AE is being tested just as much as the EUT.
- The applied stress is very dependent on cable layout and AE impedance. The current flowing into the EUT is determined by the impedance of the cable, which acts as a transmission line at high frequencies and so may have standing waves due to mismatches, and by the impedance to the reference plane of the AE. So this offers the highest uncertainty and least repeatability of all the methods.
- The probe is lossy and has a high power requirement. The higher its internal turns ratio the more power is needed, but low turns ratios affect the coupling of the probe to the cable and are effectively forbidden by the standard.

Equivalence of results

The standard does not categorically specify which transducer method to use. Its Figure 1, “Rules for selecting the injection method”, asks the first question “Are CDNs suitable?”, to which if the answer is yes they should be used. Criteria for suitability are not defined. Clause 6.2 of the second edition says that CDNs are to be preferred but are not mandatory. In the European pre-standard ENV 50141 they were mandatory for all AC and DC power supply cables, but only a recommendation appears in IEC 61000-4-6 (in clause 6.2.1.1).

It must therefore be assumed that if one laboratory decides that for a particular port a CDN is suitable, and uses it, while another does not and uses an EM-clamp, and a third elects for the current injection probe, then the results of all three laboratories are deemed equivalent.

Reference [1] investigated this equivalence and concluded

- If the Z_{AE} (see later) is maintained accurately at 150Ω then all three transducers can give very similar results; the two clamp methods differ from the CDN reference level

by less than 2dB over the range up to 10MHz, unless the current probe turns ratio is as low as 1:1.

- Any departure from 150Ω of Z_{AE} causes a deviation in the injected stress corresponding to the ratio of the total impedances for each of the clamp methods, but no change for the CDN. The deviation is equivalent for the EM-clamp and current injection probe at low frequencies, but reduces markedly for the EM-clamp at high frequencies.

Aspects of best practice

This section discusses precautions which must be taken in the test method for each of the above transducers in order to get the best repeatability.

In all cases, you must respect the rule that says the transducer-to-EUT cable length should be 10 – 30cm. Anything longer contravenes the standard. It will become **resonant towards the** top end of the frequency range, and at a quarter wavelength the common-mode impedance presented by the EUT will be transformed into its opposite: a high impedance will appear as a low impedance at the transducer, and vice versa. This introduces problems for EUTs which have cable entries more than 30cm above the ground reference plane.

These problems have been addressed in A1 to the second edition [5]. This adds an informative Annex F, “Test set-up for large EUTs”. The modified set-up uses either an elevated horizontal ground reference plane to which the CDNs are bonded, and which allows the CDN-EUT cable length to be maintained at less than 30cm; or a vertical ground reference plane, again used for bonding of the CDNs. The vertical GRP, for instance a screened room wall, is likely to be the more attractive to test labs, since it can be used for all types of EUT regardless of the actual height of their cable entries. It will also give more repeatable results than an elevated horizontal plane, which is likely to suffer from resonances caused by its own capacitance and an inductive connection to the main ground reference plane.

In all cases the dc or low-frequency current path through the transducer should be controlled to prevent saturation of the ferrite. This requires that for all circuits the flow and return conductors must go through a single transducer. For example, even if a high-power dc supply uses separate cables for its positive and negative wires these should both pass through a single M2 CDN.

CDN

Selection

Use the right one for the cable: don't use M3 for M2, M5 for M3 etc unless the CDN supplier specifically recommends this. For details see “CDN Cautions” above.

Grounding

Ground it properly. The disturbance voltage must be applied with respect to the GRP but the voltage feed from the generator is actually connected via the BNC socket on the CDN case. Therefore there must be minimal impedance between the case and the GRP, since this impedance appears directly in series with the applied stress. A metal-to-metal contact is best; any grounding strap must be short and wide since its inductance must be negligible all the

way up to 80MHz (or 230MHz). Green-and-yellow wires, always the bane of EMC engineering, are outlawed.

EM-clamp

AE CM impedance

With the EM-clamp, it is necessary to constrain the AE CM impedance (Z_{AE} at low frequencies. At these frequencies?) to 150Ω (generally below 10MHz) the EM-clamp acts mostly like the current injection probe, in that it applies current more than voltage to the cable under test, so that the impedance of the total loop is important.

However, the directivity of the clamp above 10MHz means that this requirement largely vanishes and the Z_{AE} may be uncontrolled. This is actually a happy result, because the principal difficulty in controlling Z_{AE} is at high frequencies, where stray capacitance of the AE to the ground plane, and resonances in unavoidably long cables to and from the AE, cause the most problems (but see [2]). Provided that the LF impedance is maintained at 150Ω , which can most easily be done if the AE is mains-powered with a mains CDN on its input and all ports other than the cable under test left floating, then the HF impedance can be left to look after itself.

Grounding

Like the CDN, the EM-clamp applies a form of voltage injection with respect to the ground reference plane. Therefore it is again necessary to ground it properly, with a short, direct strap and preferably with the ground plate making direct contact. It cannot be used correctly if it is not placed on and connected to the GRP. This differentiates it from other forms of clamp, such as pure decoupling clamps, common mode absorbing devices, or the MDS-21 absorbing clamp used for some emissions tests. These devices use only ferrite, to increase the common mode series RF impedance of the cable, without reference to ground.

Current injection probe

AE CM impedance

With the current probe, it is necessary to constrain the AE CM impedance to 150Ω at all frequencies. This, of course, is fundamentally difficult to achieve, and even more to confirm. The actual CM impedance at the AE port is out of the hands of the test laboratory; only the impedance of the AE itself to the GRP can be controlled, most easily using a CDN on its power supply, but at high frequencies this is compromised by its stray capacitance to the GRP. Add to this the effect of longer cables between the AE and the probe, and it can be seen that at high frequencies (typically 26MHz and above) predictability and repeatability of the stress induced by the current probe is very unlikely.

It follows from this that you should only apply the probe to short cables, preferably shorter than 60cm, and certainly less than 1m. For cables longer than this, use the EM-clamp. Some laboratories believe that a very long cable ($> 5m$) between the clamp and the AE will somehow “attenuate” the signal applied to the AE. This is nonsense; all that happens is an arbitrary and unnecessary reduction of the frequency at which cable resonance effects become significant, leading to even greater lack of repeatability.

Current monitoring

If you are using clamp application and the AE CM impedance cannot be constrained to 150Ω – which is, practically, the case for the majority of test set-ups – then clause 7.4 of the (new) standard puts further requirements in place. It states “it is necessary that the common mode impedance of the AE be less than or equal to the common mode impedance of the EUT port being tested. If not, measures shall be taken ... at the AE port to satisfy this condition.” The applied current is then limited through the use of a secondary monitoring probe to what would occur in a true 150Ω system, that is, double that which occurs in calibration, which is a 300Ω system. The measures to be taken include, as an example, the use of a CDN-M1 or 150Ω resistor from the AE to ground.

It is unrealistic under real life conditions in test labs to verify the AE CM impedance across the frequency range for every test set-up. While a procedure for doing so can be envisaged, using a spectrum analyser, tracking generator, a small coupling jig and some data reduction software [7], this would noticeably extend the time taken to complete what is already a potentially long-drawn-out test. It is also equally unrealistic to verify the EUT port CM impedance. So under real life constraints labs tend not to ensure that the common mode impedance of the AE is less than or equal to the common mode impedance of the EUT port. Although the current limiting method ensures against *over*-testing if the EUT port impedance drops to zero, it would only ensure against *under*-testing if the AE port impedance was in fact maintained at less than 150Ω . Thus laboratories are left largely without guidance in this crucial aspect of the test, and as a matter of practice it is easy for them to pay insufficient attention to controlling the AE CM impedance as the standard requires.

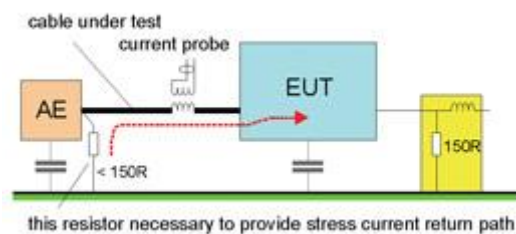


Figure 8 The problem of floating AEs

The threat is mainly that, if the AE is left floating, because for instance it is battery powered or passive and there is nowhere to connect a grounding resistor, the return path for the stress at low frequency is high impedance, being only provided by stray capacitance from the AE to the ground plane (Figure 8). Thus the EUT cannot avoid being under-tested at low frequencies since both types of clamp device inject mainly current rather than voltage at this end of the range. The lab

will ignore this, since there is no requirement on them to control the minimum injected level, and the customer won't object if their equipment passes. At higher frequencies, the situation improves because the stray capacitive impedance of larger AEs is low enough for a real test to be made.

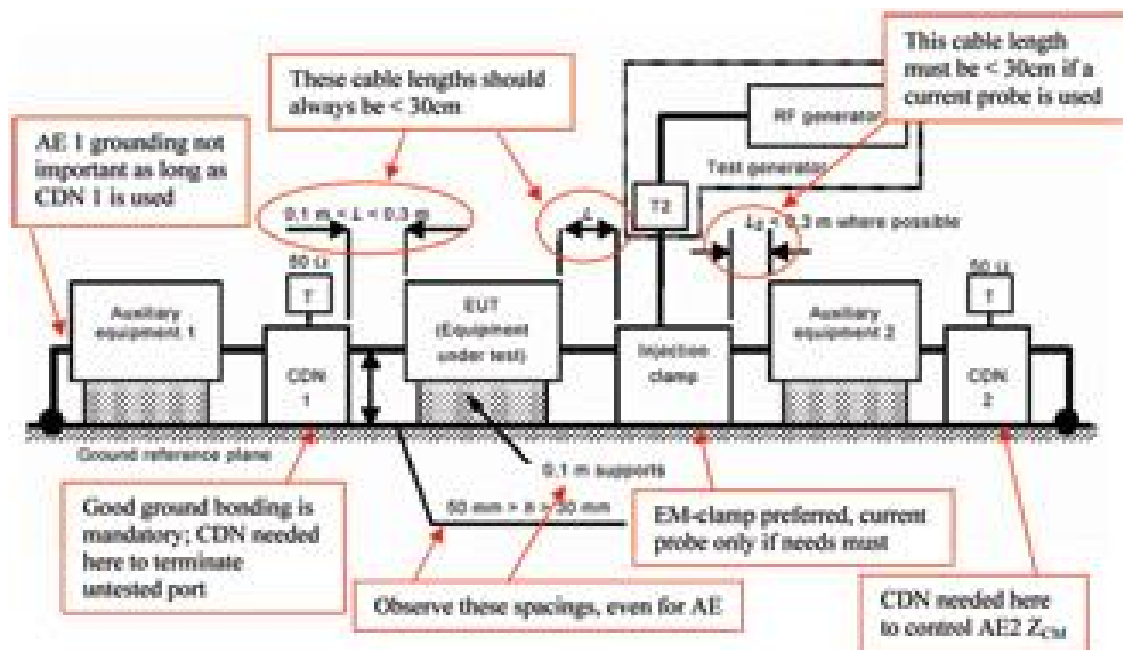
For a correctly implemented test, it is essential to find some way of ensuring an AE common mode impedance of at most 150Ω . Manufacturers' labs who regularly test only a few types of interface can create jigs for this purpose, but for a general test lab who may be faced with a wide variety of products from day to day, this is a major overhead. The article in the previous issue of EMC Compliance Journal [2] offers one solution to this problem for both the EM-clamp and the probe.

Conclusions

This paper has discussed several issues that arise from the application of IEC 61000-4-6. It is a very complex and difficult test to perform properly, especially if the EUT, AE and their cables do not conform to the simple set-ups envisaged by the standard. There is no universal guidance that can be applied for all cases, but an understanding both of the principles of the test and of the coupling transducers that it allows can guide a laboratory towards applying it in the most effective way for a given case.

Summary of best practice

The drawing below is a reproduction of fig 2b of the second edition of IEC 61000-4-6. The annotations should be self-explanatory.



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- [3] Reducing errors due to resonances in radiated and conducted EMC testing, Richard Marshall, 15th Intl. Zurich Symposium on EMC, February 18-20 2003, paper 4F1 pp 267-272
- [4] IEC 61000-4-6 second edition 2003, EMC: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields
- [5] Amendment 1 to IEC 61000-4-6 second edition, Define a new set-up for large EUTs, 77B/426/FDIS
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- [7] Use of a tee attenuator for VHF and UHF impedance measurement, Richard Marshall, to be published in the May issue of the EMC & Compliance Journal.

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Richard Marshall is with Richard Marshall Limited www.design-emc.co.uk

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ANNEX B**Shipping list**

Item	Qty	Note
RFIC46	1	
RF0250	1	
Software	1	Supplied on CD
CDNs	As ordered	
6dB attenuator	As ordered	
Cable BNC—BNC	1	RFIC46 to RF0250
Cable N—N	1	RF0250—Atten (if used)
Cable N—BNC	1	Atten to CDN
Cable BNC—BNC	1	Feedback signal
BNC right angle adaptor	2	CDN connections
50ohm termination	1	
46ZZ	As ordered	Calibration adaptors
46GP	As ordered	Ground plane
46XP	As ordered	Extension ground plane
USB cable	1	PC to RFIC46
15 pin D type plug	1	For EUT prompt
Cable cover for above	1	
4 pin DIN cable	1	RFIC46 to RF0250 (interlock)

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Annex C

Software installation

The software is supplied on a CD, together with any relevant calibration files required for CDNs, and a copy of this manual in pdf format.

CD Contents

RFIC_4_6.msi Main program install file.

USB_Drivers

-DeVaSys_UsbI2cIo_Drivers_32_bit.msi

-DeVaSys_UsbI2cIo_Drivers_x64.msi

Calibration Files

*.txt * = device serial number

The main software is provided as the .msi install file. Running this file will automatically create the correct directories and install the necessary files.

This install should work on any current version of Windows.

Once the main program is loaded, the USB drivers must then be loaded. There are 2 driver install .msi programs on the CD. One is for 32 bit operating systems, the other for 64 bit. Run the install to suit your PC.

The directory structure:

...../Program Files/Laplace Instruments Ltd/RFIC-4-6

This contains:

Program file	RF46.exe
Initialisation file	RF46.INI
USB interface file	Laplace USB.txt
USB driver	Usbi2cio.dll

...../My Documents/Laplace Instruments Ltd/RFIC-4-6/Results

This is the default directory for all saved results files.

...../My Documents/Laplace Instruments Ltd/RFIC-4-6/User Apps Data

This contains:

Analyser calibration file: pscan.csv
Any other calibration files (eg for enhanced CDNs) These are loaded when the relevant utility on the main program is selected.

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